FOREST INVENTORY DESIGN FOR AFFORESTATION AREAS

by

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Abstract

This paper deals with a two stage sampling design for afforestation inventories which was recently adopted for the evaluation of large plantation areas in the North-West Frontier Province. Major considerations for designing such an inventory are elaborated and the complete procedure of selecting an appropriate design, implementing it in the field, data processing and interpretation of the results are described.

INTRODUCTION

In the North-West-Frontier Province large areas of unclassified land,culturable waste and rangeland have been afforested during the past twenty years under various projects, either locally funded or assisted by foreign donors. The forestry statistics of the province show that about 156 000 hectares have been planted until 1986. To increase the total forest area of the province by 7% the afforestation target will be 36 000 hectares per year in a twenty year programme (Ali Akbar et al, 1986).

The above facts show clearly the high priority so far given to afforestation activities and it is expected that this work will be continued even more intensively in the future.

Due to the fact that such afforestation programmes involve significant inputs in terms of funds, labour and organization, the question concerning the success of a particular plantation work is of high importance to the funding and/or implementing agencies.

Therefore, important parts of an efficient control system would include continuous monitoring of the ongoing afforestation activities (planting stock, nursery and planting techniques, etc) as well as repeated evaluation of already established plantations for at least 10 to 15 years after planting.

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The first step in evaluating an afforestation area is the description of its present status which always should be done in quantitative terms (number of plants per hectare, tree species composition, survival rate, and height growth) using sampling techniques for data recording in the field and computer-aided data processing.

This paper describes a sampling inventory procedure (design, field work,data compilation), which was adopted during evaluation of about 25 000 hectares of afforested areas under the "Income Regenerating Project for Refugee Areas" in North West Frontier Province (BOKHARI, 1989**).

OBJECTIVES

In general, afforestation inventories have the following aims:

- collect and analyse area and tree related data of the established plantation
- provide reliable information on the present status of the afforested areas which is the basis for evaluation of the past work and for decision making concerning future operations (e.g. restocking, weeding, etc).

Sampling Design

Basic considerations

Before one arrives at a decision about a suitable sampling design, the following factors have to be considered:

- Size of the area and its structure
- Variables to be studied
- Desired accuracy
- Variability of parameters in the area being studied
- Implementation in the field

Size and structure of the area

The whole area of afforestation (25 000 hectares) consists of more than 200 sub-areas, which are scattered in clusters over the

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** The data and results have been provided by Mr. A.S. Bokhari, Islamabad. His cooperation and permission is much appreciated.

entire province. Each cluster is called a sub-project and has got different sub-areas with sizes ranging from about 2 ha to 1800 ha.

Variables to be studied

Because of considerable differences between the sub-projects concerning ecological conditions (rainfall) and tree species planted, it was decided to carry out the inventory separately for each sub-project. The following variables should be studied:

- Area (stocked, blank)
- Mode of establishment (planting or sowing)
- Number of plants per hectare (height classes, species)
- Survival rate
- Natural growth

Desired accuracy and variability of parameters in the area

The intensity of sampling (the number of sample plots required) depends on a given accuracy and on the variation of the parameter in question.

In this inventory the target was fixed as follows:

The total number of plants per hectare (acre) should be determined by a standard error of $\pm$ 10%.

The results of a reconnaissance inventory in one of the sub-projects reveal that about 200 plots ($50m^2$ circles) are sufficient to achieve the desired accuracy. As it becomes clear later on from the final inventory results, the variation coefficients between the sub-projects show considerable differences. To simplify the work, it was decided to use a density of 1 plot per 4 ha. Generally this led to lower standard errors but sometimes higher ones occurred which were tolerated.

Implementation in the field

It is well known that the largest inputs in terms of funds and labour are required for field work. Therefore, the inventory must be designed in such a way to minimize the expenditures and ensure an easy and quick implementation.

The final inventory design

Size of the sample plot

Presuming that most of the planting was done according to the prescribed spacing of 10x10 feet and that the area was fully stocked, it was calculated that a minimum of 4 and a maximum of 7 plants (Figure 1) would fall in a circular plot with an area of $50m^2$ (radius 4 meters).

The layout of such circles on sloped terrain is easy. Due to the small number of plants in the sample, recording errors are unlikely to occur.

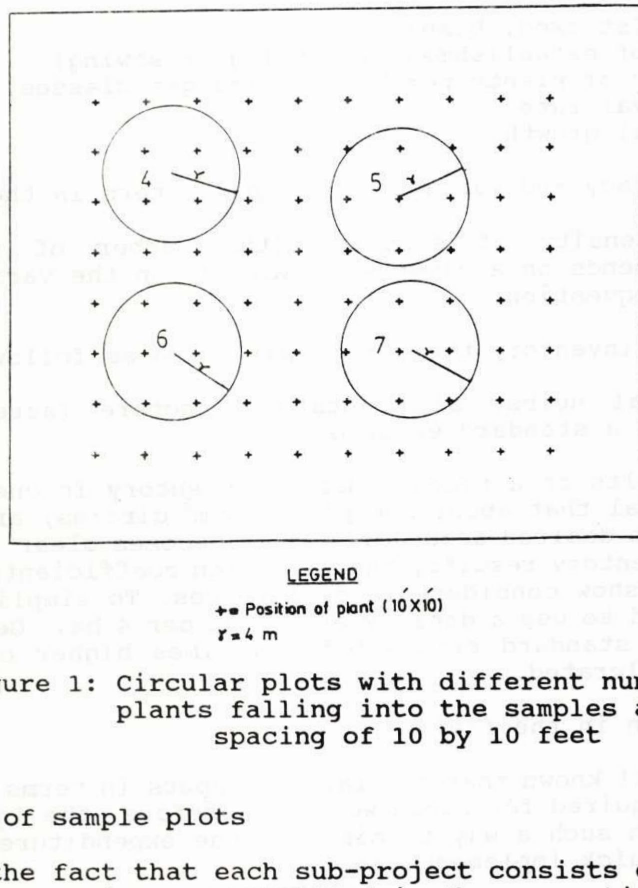

Figure 1: Circular plots with different number of plants falling into the samples at a spacing of 10 by 10 feet

Distribution of sample plots

Due to the fact that each sub-project consists of many areas of varying sizes which are scattered in the respective region, it was not advisable to layout the required number of sample plots in a systematic grid covering the whole area. In order to concentrate all the measurements on a few areas, a two-stage sampling (HUSCH et al, 1982) was used. The procedure is as follows:

First stage: Out of a list of all afforested areas of a sub-project some areas are randomly selected. Here it was decided to use a list-sampling, so called PPS-sampling, with Probability Proportional to the Size of the areas, so that a larger, more important area, gets a better chance to be selected than a smaller one.

Second stage: In each of these randomly selected areas a systematic sampling was carried out using the circular plots described above in a quadratic grid.

Practical Implementation of the Inventory

With the help of basic data related to the sub-project "Soka Nullah Watershed Management and Forestry in Sobangali Range" the procedure adopted is explained below.

First stage

List-sampling with varying probabilities (a priori):

Sampling in the first stage was carried out by listing all afforestation units giving area acreage according to the progress report of the Forest Department. Since the size of each area was known before starting the sampling work, it is called "a priori" list-sampling.

Table 1: Basic data for list-sampling

Area Number (1)	Area in Acre (2)	Cumulative Total (3)	Associated Number (4)
1	63	63	1-63
2	82	145	64-145
3	82	227	146-227
4	85	312	228-312
5	85	397	313-397
6	19	416	398-416
7	42	458	417-458
8	50	508	459-508
9	109	617	509-617
10	60	677	618-677
11	70	747	678-747
12	70	817	748-817
13	75	892	818-892
14	44	936	893-936
15	47	983	937-983
16	60	1043	984-1043
17	91	1134	1044-1134
Total	1134		

The above Table shows all areas of the sub-project along with their acreage (2) and the cumulative total (3). Column 4 indicates a set of consecutive integers ranging from 1-1134, the total area of the sub-project. They were used to select the areas according to their respective size. For this sub-project the decision was made to select 8 areas for field measurements. Consequently 8 random numbers were drawn from a random list (FISHER <u>et al</u> 1957) as under:

49,64,92,85,44,56,34,19

They were then multiplied with the cumulative total to obtain a random number, which ranges between 1 and the cumulative total (1134).

An example is illustrated as under:

1134 * 0.49 = 556

1134 * 0.64 = 726 and so on

If the random number fell into its respective interval given in column 4 of Table 1, then this area was selected for the purpose of field inventory. The same calculation was done for all other random numbers and the results of the selection procedure are shown in Table 2.

Table 2: Results of the list-sampling procedure

Random Number drawn(calculated)	Areas chosen	Name of area
556	9	Shadial-II
726+	11	Chamhad-II
1043	16	Bansari
964	15	Sandogali
499	8	Doboola
635	10	Budial
386	5	Ruknuran
215	3	Talhand

Example: + This random number falls into the interval 678-747 (Table 1); therefore area No.11 is chosen

Second stage

<u>Systematic sampling with fixed area plots:</u>

According to the already described procedure, a systematic grid with a plot to plot distance of 200 m was laid out covering all eight of the afforested areas which were chosen in the first stage. A tally sheet (Figure 2) was designed to record the following characteristics on each sample plot:

1. - Number of sample plot
2. - Mode of establishment
3. - Year of afforestation
4. - Number of plants in their respective height classes by species
5. - Number of empty pits
6. - Number of naturally growing plants

TALLY SHEET

AFFORESTATION AREAS

Team: ______ Date: ______
Location: ______ Area No.: ______
Year of Afforestation: ______ Size: ______

Plot No.	Species	Height	Empty Pits	Natural Growth
	Acacia			
	Eucalypt.			
	Ailanthus			
	Robinia			
	Pine			
Mode of Establishment	Planting	Sowing		

Figure 2: Tally sheet for data recording in the field

Data-Processing

After completing the field work, the information from each tally sheet was stored in a personal computer (IBM,PC/AT) using a word processing package (Word Star) which can also work as a simple data-bank programme.

The data calculation itself was done with the help of a statistical programme package (SPSS/PC, Statistical Package for the Social Sciences, NORUSIS, 1986) using different descriptive data analysis procedures like frequencies, basic statistics (mean, standard deviation, etc.) and routines for data transformation.

The following results have been calculated:

- Percentage of area stocked with or without natural growth
- Percentage of blank area with or without natural growth
- Species composition (plant number per acre)
- Percentage survival
- Height classes (one feet) by species and by area (plant number per acre)

The total time spent on data-processing comes to 12 man days (6-8 working hours/day). Out of these, 10 days were required for entering the data into the computer and only 2 days were spent on designing and running the computer programmes.

RESULTS

Detailed results for the sub-project

The results of all inventorized areas are shown in Tables 3,4 and 5. Due to the adoption of a two-stage sampling design, figures such as area percentages and number of plants per acre are valid for the entire area of this sub-project. One example from each Table is given below:

- 36.8% of the total sub-project area is stocked whereas 63.2% is blank (Table 3)

- The species composition of the sub-project is Acacia 20.7%, Eucalyptus 30.1%, Ailanthus 6.7%, Robinia 5.7%, and Pine 36.8% (Table 4)

- Concerning the heights of the plants, the results are given in Table 5. It shows that 96 plants/acre are not higher than 1 foot, 37 plants/acre are in the height class 1-2 feet and so on.

Similarly, all other details of the results are used for the evaluation of the present status of the afforestation areas. They are indications of the success or failure of the work done and they provide valuable information for planning of future activities such as restocking, change of species, mode of planting, etc.

Table 3: Percentage of Stocked Area and Mode of Planting

Area No	No of Sample Plots	Stocked area			Blank area			Mode of Planting		
		1	2	3	1	2	3	S	P	S+P
9	7	-	28.6	28.6	14.3	57.1	71.4	-	100	-
11	8	37.5	62.5	100	-	-	-	-	100	-
16	5	-	40.0	40.0	40.0	20.0	60.0	-	100	-
15	9	-	22.2	22.2	22.2	55.6	77.8	-	100	-
8	5	-	20.0	20.0	20.0	60.0	80.0	-	100	-
10	6	-	33.3	33.3	16.7	50.0	66.7	-	100	-
5	6	-	50.0	50.0	16.7	33.3	50.0	-	100	-
3	5	-	-	-	-	100	100	-	100	-
Mean		4.7	32.1	36.8	16.2	47.0	63.2	-	100	-

(Legend: 1 : With natural growth, 2 : Without natural growth, 3 : Total, S : Sowing, P : Planting, S+P : Sowing & Planting)

Table 4: Species Composition, Survival Rate and No.of Pits per Acre Indicative of Spacing (Mean Values)

Area No	SPECIES 1	2	3	4	5	6	7	8	9
9	-	328.2	-	-	-	328.2	41	369.2	-
11	174.4	-	82.1	92.3	-	348.8	153.7	502.5	71.8
16	-	82.1	-	-	328.2	410.3	164.0	574.3	-
15	-	82.1	-	-	82.1	164.2	205.0	369.2	-
8	-	-	-	-	82.1	82.1	328.1	410.2	-
10	164.1	-	-	-	-	164.1	246.1	410.2	-
5	-	-	27.4	-	107.4	136.8	328.1	464.9	-
Mean	48.0	70.3	15.6	13.2	86.0	233.5	209.4	442.9	10.3

(Legend 1 : Acacia, 2 : Eucalyptus, 3 : Ailanthus, 4 : Robinia, 5 : Pine, 6 : Total, 7 : No.of empty pits, 8 : Total No. of pits, 9 : Natural growth)

SPECIES COMPOSITION IN STOCKED AREA -SURVIVAL RATE (IN STOCKED AREA) 52.7%

- ACACIA 20.7%
- EUCALYPTUS 30.1%
- AILANTHUS 6.7%
- ROBINIA 5.7%
- PINE 36.8%

100.0%

Table 5: Number of Plants per Acre in each Height Class

SPECIES	HEIGHT IN FEET										
	1	2	3	4	5	6	7	8	9	10	TOTAL
ACACIA	39.6	7.3	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.4
EUC	5.9	17.6	29.3	17.6	0.0	0.0	0.0	0.0	0.0	0.0	70.3
AIL	5.4	2.9	1.5	0.0	2.9	2.9	0.0	0.0	0.0	0.0	15.6
ROBINIA	0.0	2.9	0.0	1.5	0.0	0.0	0.0	2.9	1.5	4.4	13.2
PINE	44.9	5.9	5.9	0.0	0.0	11.7	0.0	5.9	11.7	0.0	85.9
PLANTS PER ACRE OF STOCKED AREA (ROUND FIGURES)	96	37	38	19	3	15	0	9	13	4	234

Accuracy

As already discussed, the desired accuracy for this inventory was defined as ± 10% standard error of the total number of plants per hectare (acre) separately for each sub-project. The following list shows some of the main sub-projects alongwith the number of plots recorded and the obtained standard error.

Sub-project	No.of sample plots laid out	Standard error (%)
Kohat Reforestation(Ph.I)	483	± 3.6%
Shadigali Range (Ph.I)	221	± 5.2%
Sobangali Range (Ph.I)	286	± 5.2%
Kohat Reforestation(Ph.II)	187	± 6.4%
Haripur Range (Ph.II)	91	±13.6%
Shadigate Range (Ph.II))	37	±12.0%
Sobangali Range (Ph.II)	51	± 6.5%
Bhaheri Khaki Afforestation	110	±16.0%
Khanpur Afforestation	200	± 9.3%

The table shows clearly that the number of sample plots deviates considerably from the prefixed number of 200 whereas the standard error is mostly below ± 10% except in a few cases. The reasons are:

- The results of the reconnaissance inventory could not reflect totally the actual variation for the entire area.
- The decision to fix the intensity of the sampling (1plot/4 hectares) was based on the variation found in the area where the reconnaissance survey was carried out. In some other areas the variation was actually much less which led to very small standard errors.

Concerning the achieved accuracy one can conclude that the whole inventory work was done conservatively (more plots laid out than actually required). It also shows the difficulties involved to find an optimum number of sample plots without spending too much time on work intensive reconnaissance surveys.

CONCLUSION AND RECOMMENDATIONS

For designing and implementing further afforestation inventories the following recommendations can be drawn from the above paper:

- Use a two-stage design (list-sampling in combination with systematic sampling) wherever the afforestation area is split into different sub areas which are scattered in a certain region.
- Use fixed area circles with sizes according to the prescribed spacing.
- Conduct a short reconnaissance survey to estimate the crop variation in order to determine the number of plots required to obtain a given accuracy.

Finally, one can conclude that the forest inventory design described above, including its field work and data-processing procedure, proved to be practicable under conditions found in the afforestation areas. The design is statistically more demanding and the processing has to be done by computers. Nevertheless the procedure can easily be implemented by the forest officers (designing and processing) as well as the field staff (data-recording) after being trained for a few days.

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