Leaflet No.-20/81-82

Government of the Union of Myanmar
Ministry of Forestry
Forest Department

Optimum Subplot for the National Forest Inventory of Burma

Dr. Kyaw Tint, Htun Lynn
Forest Research Institute
January 198

သစ်တောသယံဇာတ စာရင်းကောက်လုပ်ငန်းအတွက် အသင့်တော်ဆုံးနမူနာအကွက်ငယ်ကို စူးစမ်းလေ့လာခြင်း

ကျော်တင့် နှင့် ထွန်းလင်း
သစ်တောဦးစီးဌာန

စာတမ်းအကျဉ်းချုပ်

သစ်တောသယံဇာတ စာရင်းကောက်လုပ်ငန်းအတွက် .၀၄၊ .၀၅၊ .၀၆၊ .၀၈ နှင့် .၁၀ ဟက်တာဧရိယာရှိသာ စက်ဝိုင်းပုံနမူနာ အကွက်ငယ် (၅)မျိုးကို စမ်းသပ်ခဲ့ပါသည်။ စမ်းသပ်ကိန်းဂဏန်းများကိုအခြေခံ၍ ဒမ်းမီးကိန်းရှင်များကိုအသုံးပြုပြီး လိုင်းဖောက်ရာ၌လည်းကောင်း၊ သစ်ပင်တိုင်းတာရာ၌လည်းကောင်း ကြာသည့်အချိန်၊ ခရီးအကွာအဝေး၊ ပင်စုနှင့်တောတောင် အခြေအနေများ တခုနှင့်တခု ဆက်စပ်မှုပြ ရီဂရက်ရှင်းများဖော်ထုတ်ပြီး၊ စမ်းသပ်သောအကွက်ငယ်များ၏ နှိုင်းယှဉ်တိကျမှုများကိုလည်း၊ အသေးစိတ်စီစစ်ထားပါသည်။ စမ်းသပ်စီစစ်ချက်များအရ .၀၈ ဟက်တာဧရိယာရှိသော နမူနာအကွက်ငယ်သည် စာရင်းကောက်လုပ်ငန်းအတွက် အသင့်တော်ဆုံး ဖြစ်ကြောင်းတွေ့ရှိရပါသည်။

Optimum Subplot for the National Forest Inventory of Burma

Kyaw Tint and Htun Lynn
Forest Department

Abstract

Five different circular subplots of sizes .04, .05, .06, .08 and .10 ha were tried. Using dummy variables, "giant size" regressions were developed between time, distance, stand and site parameters, which were likely to be useful in future planning. Relative net precisions of the tested unit types were analysed in detail. The results of the analysis indicated that the .08 type was the best.

Contents

1. Introduction

For procurement of adequate and continuous information about the current state and rates of change of the timber resources of the country, the Forest Department will conduct National Forest Inventory (NFI) on a continuous basis in cooperation FAO and UNDP.

The sampling design of the NFI has been planned to use the theory of Sampling with Partial Replacement (SPR). For field convenience and efficiency, sample plots, temporary as well as permanent, will be made up of several circular subplots. With the NFI Project scheduled to start in 1981-82, it is very critical that the optimum size of subplots, their optimum number and structure in a sample plot be decided prior to the start of the main inventory.

As such an extensive pilot survey was carried out in 1980-81 in four out of six forest divisions of the Project First Priority Area. The pilot survey was intended to solve a number of problems –

First - to decide, as stated earlier, on the optimum size of subplots, and optimum size and structure of sample plots

Second - to determine the best sampling methodology for tree volume table construction, and

Third - to fix sampling intensity of the NFI System to meet the prescribed precision requirements at minimum cost.

The experiment was divided into two phases. First phase concerned with the determination of the size of the subplot which is not only cost-efficient but most convenient also of establishment. The second phase of the research project was worked out to give solutions to other problems listed above.

The present paper deals with the first phase of the pilot survey. It describes in brief the topographic and stand conditions of investigated populations, the methods of data collection and analysis, and the results of the statistical analyses.

2. Experimental Design

Four experimental sites were selected in Palwe and Yeni reserved forests, Pyinmana Forest Division, and in Ngalaik and Taungnyo reserved Forests, Yamethin Forest Division. The sites were selected in such a way that the subplots covered, different forest and topographic conditions.

From a point defined as the centre of the experimental area two variants were tried.

2.1 Variant I. Random combination of subplot size and interval

Four random combinations of sizes such as 400 m^2, 500 m^2, 600 m^2, 800 m^2 and 1000 m^2 with intervals such as 40m, 50m, 60m, 70m and 80m were drawn. The first combination was run (under line-plot system) due north, the second due east, the third due south and the fourth due west from the starting point mentioned in S.2.

2.2 Variant II. Combination of small sizes with small intervals, and of big sizes with big intervals

The following four combinations were experimented with: -

1. Subplot size 400 m^2 with 25 m interval
2. Subplot size 600 m^2 with 30 m interval
3. Subplot size 800 m^2 with 35 m interval
4. Subplot size 100 m^2 with 25 m interval

The first combination was run in the direction of North-East the second South-East, the third South-West and the fourth North-West from the starting point.

Number of subplots to be laid out on a line was not predetermined. Daily operation continued till the end of the working hours.

3. Field Work

Four inventory crews conducted field work in December, 1980. An inventory crew consisted of one crew leader, two assistant crew leaders and five labourers. Altogether 573 subplots were measured in four localities. Their distribution by size and locality is given in table 3.1.

Table 3.1 Distribution of subplots by size and locality.

Forest Reserve	Area of subplot, m^2					Total
	400	500	600	800	1000	
1	2	3	4	5	6	7
Palwe	43	9	28	25	20	125
Yeni	40	10	28	26	24	128
Ngalaik	32	12	35	28	27	134
Taungnyo	50	15	44	43	34	186
Total	165	46	135	122	105	573

Number of subplots of size 500 m^2 each was least since they were not included in the second variant.

3.1 Measurement and Records

The following records and measurements were made during the field work:

a – distance to subplot, m
b – area of subplot, m^2
c – time to cover the course, min. ,
d – time to finish operations on the subplot, min. ,
e – land area class along the course,
f – land area class on the subplot,
g – undergrowth along the course,
h – undergrowth on the subplot
i – maximum, minimum and average gradients of the course, in degrees.
j – maximum, minimum and average gradients of the subplot, in degrees
k – breast height or reference diameter of trees 10 cm diameter and up on the subplot

by species.
Various measurements and records were made according to the general instruction set by Kyaw Tint (1980).

3.2 Errors in Tree Location

In sampling a forest crop using either fixed or variable plots, locating trees and border line trees introduces bias, the intensity of bias depending on the shape and size of the plot. The investigate tree location errors for different plot size, the following arrangement was thus made in Yeni reserve. The Variant II of the experiment was executed by four field crews, each crew, and usual, laying out a certain plot size at a fixed constant interval. On the following day each crew conducted the line-plots to his right run by a different crew on the previous day, the former sort of checking the work of the latter. It took measurement of the distance of every tree from the subplot centre.

4. Results of Analysis

The total number of subplots, as stated in S.3 amounted to 573. They covered dense forests in upper Palwe reserve, fairly dense forests in Ngalaik and Yeni reserves and highly disturbed forest in Taungnyo reserve. Subplots also covered fresh and old taungyas in Ngalaik, Taungnyo and Yeni forests. In Taungnyo most of the area where the plots fell were cultivated.

Configuration was very steep in Palwe, moderate in Naglaik and Yeni, and undulating in Taungnyo reserve.

The land area classes covered by the survey happened to be moist upper mixed deciduous forest (coded 11) dry upper mixed deciduous forest (coded 12) lower mixed deciduous forest (coded 13) taungya (fresh clearing) (coded 22) taungya (abandoned or old) (coded 23), regrowth (coded 24), and high indaing (coded 17).

4.1 Area and Number of Trees

Distribution of total number of trees by subplot size is illustrated in fig. 4.1 .

Blank subplots numbered 24 out of a total of 165 i.e . 14.5% for 400m^2, 7 for a total of 46 i.e. 15.2% for 500m^2 18 for a total of 135 i.e. 13.3% for 600m^2, 7 for a total of 122 i.e. 5.7% for 800m^2, and 8 for a total of 105 i.e. 7.6% for 1000m^2.

The correlation between subplot size and number of trees (10 cm d +, all species combined) it contains was poor with a coefficient of 0.282, although there is a tendency of tree numbers rising with increasing subplot size (see fig. 41).

Using dummy variables, regression of the number of trees on the size of the subplot may be explained by

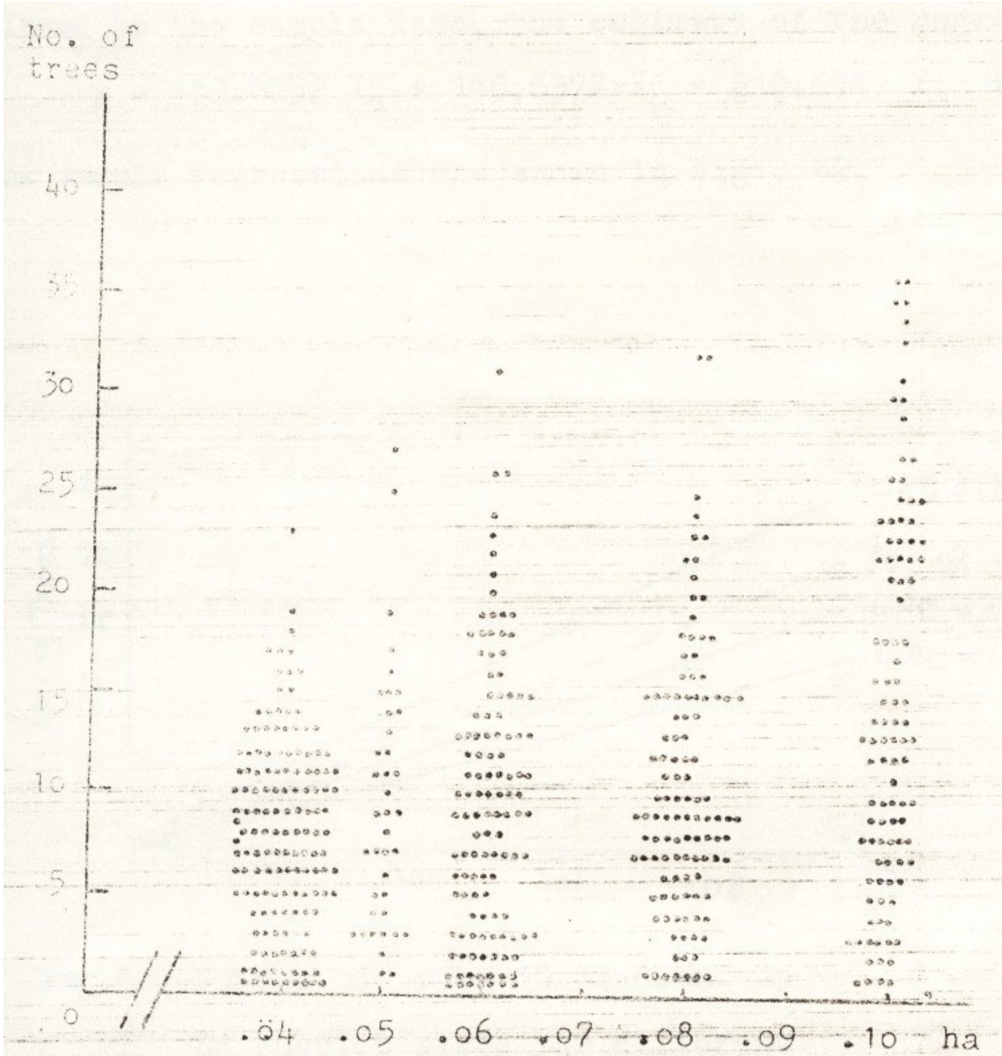

Fig. 41. Distribution of subplot total number of trees by subplot sizes.

$$y = B_1 X_1 + B_2 X_2 + B_3 X_3$$

where y = number of trees

X_1= Area of the subplot if LAC =11
  = 0   otherwise

X_2= Area of the subplot if LAC =12
  = 0   otherwise

X_3= Area of the subplot if LAC =17
  = 0   otherwise.

Fitted to the sample data, the estimate of the regression is

$$y – 152.0232 X_1 + 140.6378 X_2 + 210.6747 X_3 \quad (41.1)$$

The sample regressions are shown in Fig . 4.2.

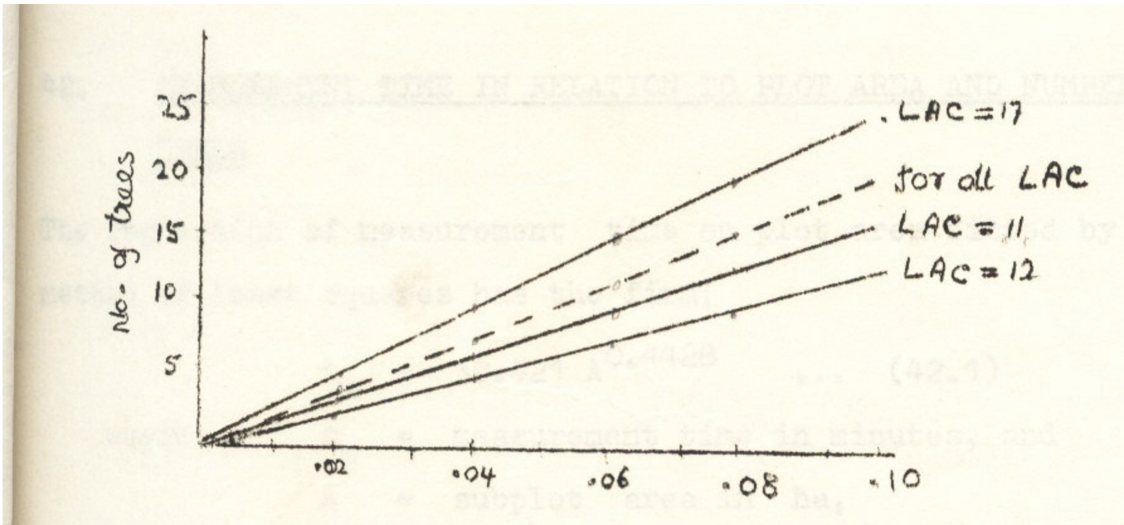

Fig.42. Number of trees 10 cm d. and up on subplot sizes for different land area classes.

The sample F value for the null hypothesis $B_1 = B_2 = B_3 = B$ is 14.69 with 2 and 469 degrees of freedom. The critical F value at the 99% probability level being 4.6 the null hypothesis is rejected. Again the hypothesis that $B_1 = B_2$ (i.e the regressions between LAC 11 and 12 are the same) was tested. The sample value of F is 0.69 for 1 and 469 degrees of freedom. As this value is not significant (the critical F value 99% probability level being 6.63) the null hypothesis is accepted.

Hence, the giant size regression (41.1) reduces to

$y = 150.38 X^* + 210.6747 X_3$ (41.2)

where x^* = Area of the subplot if LAC = 11 or 12.
= 0 otherwise
X_3 = Area of the subplot if LAC = 17
= 0 otherwise.

4.2 Measurement Time in Relation to Plot Area and Number of Trees

The regression of measurement time on plot area fitted by the method of least squares has the form;

$t_m = 30.421 A^{0.4428}$ . . . (42.1)

where t_m = measurement time in minutes, and

A = subplot area in ha,

$r^2 = 0.200$

Unlike in normal or near-normal forests, number of trees is very poorly correlated with the plot area in irregularly highly disturbed tropical forests. Accordingly, measurement time also does not have a strong relationship with the area.

Obviously, the measurement time has much better correlation with the total number of measurable trees on the subplot (r = 0.669). It fits the form:

$t_m = 2.538988 \text{ X } N^{0.6067143}$ (42.2)

$X^2 = 0.663$

Although a larger reduction in SSE was achieved by constructing a predictor of measurement time based upon total number of trees as in the equation (52.2), the use of plot area in the function as in (42.1) has wider practical application for plot optimization.

Instead of treating measurement time as a function of a single variable, either area or number of trees, if we treat, it as a function of both variables, it fits the form:
$t_m = 4.640 + 0.37 N + 3.634437 AN$ (42.3)

The model explains 68% of the variation about the prediction line. It is more realistic, of course, since it has considered both of the two most influential independent variables. On the other hand, to predict "t_m", "N" will have to be predicted first, which will further add up errors in the final estimate.

4.3 Alignment Time

Time taken in aligning the course through the forest is primarily a function of the land area class (LAC), undergrowth (UG), gradient (G) and length (L) of the course. Out of these your variables, G and UG cannot be controlled or known in advance. Their effect on alignment time, t_a, was therefore assumed to be included in the experimental error.

It would seem reasonable to assume that the regression function of t_a on 1 you given LAC is of the linear form

$t_a = b_1 + b_2 \, 1$

The giant-size regression of t_a on 1 and LAC may be defined as

$R_1 : y = B_{11} X_{11} + B_{12} X_{12} + B_{21} X_{21} + B_{22} X_{22} + B_{31} X_{31} + B_{32} X_{32}$

Where $y = T_a$

and $X_{11} = 1$ if LAC =12, or equal to 0 otherwise
(that is , LAC = 11,17)
$X_{12} = 1$ if LAC = 12, or equal to 0 otherwise
(that is , LAC =11,17)
$X_{21} = 1$ if LAC = 11, or equal to 0 otherwise
(that is , LAC = 12,17)
$X_{22} = 1$ if LAC = 11, or equal to 0 otherwise
(that is , LAC = 12,17)
$X_{31} = 1$ if LAC = 17, or equal to 0 otherwise

(that is , LAC =11,12)
X_{32} = 1 if LAC = 17, or equal to 0 otherwise
(that is, LAC = 11,12)

When fitted to the field data, the giant-size regression has the following form
$y = 3.7988\ X_{11} + 0.1393\ X_{12} + 2.5358\ X_{21} + 0.2116\ X_{22} - 1.3091\ X_{31} + 0.3012\ X_{32}$
The following hypotheses were tested: -

1. The regressions have the common intercept, i.e

$B_{12} = B_{22} = B_{32}$

The above statistical tests have indicated that the regression line for MUND and that for DUMD are parallel, and that the start-up times in DUMS and Indaing are the same. Thus, the selected giant – size regression has the form:

$y = 0.17513\ X_{11} + 0.210\ X_{12} + 2.5795\ X_{21} + 0.2106\ X_{22} + 0.17513\ X_{31} + 0.2681\ X_{32}$

OR

$t_a = 0.17513 + 0.2106\ 1$ for DUMD (43.1)

$t_a = 2.5795 + 0.210\ 1$ for MUND (43.2)

$t_a = 0.17513 + 0.261\ 1$ for Indaing (43.3)

The alignment time as a function of a single variable, 1 for all types has the following form
$t_a = 0.3759\ 2\ 1^{0.691359}$

with $n^2 = 0.505$ (43.4)

In the above expressions t_a is in crew minutes and 1 in meters. The alignment (or cutting) was done by one forester and two labourers using a hand compass and a topopoly chain. In the present study in addition to aligning and cutting lines, the crew also took measurements of the slope of the course.

4.4 Cost of Sampling

Cost of sampling a unit consists of two components (1) cost of alignment and (2) cost of measurement. If the cost is expressed in time, the cost model may be represented by

$t_u = t_n + t_m$ (44.1)

where t_u = cost of sampling a unit

For sample survey that involves “n” sampling units, the total cost function is

$$T = \sum_{i=1}^{n} (t_{m,i} + t_{m,i}) \qquad (44.2)$$

Where, T = total cost of the survey = $\sum_{i=1}^{n} t_{u,i}$

Table 44.1 shows cost of sampling for different subplot sizes in crew minutes. The estimation is based on varient II, and equations 42.1, 43,4 and 44.1.

Table 44.1 Cost of sampling for different subplot sizes in crew minutes

Subplot size ha	Distance m	Travel time, crew min	Measurement time, crew min	Total time, crew min
1	2	3	4	5
.04	25	6.168320	7.314180	13.5125000
.05	30*	7.227468	8.073789	15.301257
.06	30	7.227468	8.753	16.0
.08	35	8.262652	9.941725	18.205377
.10	40	9.280575	10.974214	20.254791

* not included in Variant II

4.5 Optimum Subplot

To compare the efficiencies of five different subplots, namely, .04, .05,.06,.08 and .10 ha, variance among unit totals of trees of all species were computed and reduced to a common basis. If the relative unit size is denoted by M_u, and variance among unit totals by S_u^2 then the reciprocal of the variance reduced to a common basis is $\frac{M_u}{S_u^2}$.

Cost of plot measurement is expressed in crew minutes and represented in Col. 4, table 44.1. Derived from formula (42.1), costs of taking a one-hectare sample by different plot types are given in table 46.1. If the cost of taking a given bulk of sample is denoted by , and the reciprocal of the comparable variance multiplied by the inverse of the cost, we obtain $M_u /(C_u^1 S_u^2)$ which indicates comparable precisions of different plot types (Cochran, 1963).

Alternatively, if .04 unit is chosen as a standard and given a value of 100, the precisions of other unit sizes relative to that of .04, may be estimated from the equation

$$\text{RNP} = 100 \ \frac{M_u . C_{.04}^1 . S_{.04}^2}{M_{.04} . C_u^1 . S_u^2} \qquad (45.1)$$

$M_{.04} C_u^1 S_u^2$

where,
RNP = relative net precision, and
u = .05, .06, .08, and .10 has plot type.

Table 45.1 shows relative net precision for each unit size for each forest reserve and all reserves combined.

Table 45.1 Relative net precisions

Steps in Compution	**Type of unit**				
	.04	**.05**	**.06**	**.08**	**.10**
1	**2**	**3**	**4**	**5**	**6**
M_u = relative size of unit	1.00	1.25			
C_u^1 = Cost of taking a one-hactare sample,min	182.8545	161.4758	145.8773	124.2716	109.7422
PALWE RESERVE					
S_u^2 = estimated pop. variance per unit in no. of all trees	13.950	47.748	58.171	27.342	92.87

Table 45.1 Relative net precisions (Contd)

Steps in Computation	Type of unit				
	.04	.05	.06	.08	.10
(1)	(2)	(3)	(4)	(5)	(6)
$M_u / (C_u^1 S_u^2)$	.00039203	.00016212	.00017677	.00058861	.00024529
Relative net precision	100	41	45	150*	63
NGALAIK RESERVE					
S_u^2	17.738	44.236	41.512	28.494	92.775
$M_u / (C_u^1 S_u^2)$	.00027707	.00017500	0024770	.00056481	.00024555
Relative net precision	100	63	89	204*	89
TAUNGNYO RESERVE					
S_u^2	20.399	8.744	19.643	26.061	50.737
$M_u / (C_u^1 S_u^2)$	.00026809	.00088530	.00052347	.00061754	.00044900
Relative net precision	100	330*	195	230	167
YENI RESERVE					
S_u^2	23.785	29.214	46.840	53.993	78.641
$M_u / (C_u^1 S_u^2)$	.00022993	.00026498	.00021953	.00029807	.00028968
Relative net precision	100	115	95	230*	126
ALL RESERVES					
S_u^2	24.990	44.170	49.106	45.401	102.461
$M_u / (C_u^1 S_u^2)$	.00021884	.00017526	.00020940	.00035448	.00022233
Relative net precision	100	80	96	162*	102

*best unit.

The analysis of the table (table 46.1) has indicated that .08 unit was best in four and second best in one cases out of five. Units of .04 and .10 ha were second best in two cases each, and .06 ha in one. Subplot type .05 was best in Taungnyo reserve, third best in Yeni, but turned out to be worst in the remaining three cases.

4.6 Non-Sampling Error Due to Borderline Trees

To study the effect of subplot size on the correct as to whether a tree is in or out, repeated measurement were taken in Yeni reserve (see S.32). Altogether 76 subplots of four sizes were set. As stated earlier, repeat enumeration was done very carefully, taking distance measurement of every tree on the subplot. The number of trees counted during repeat enumeration could, therefore, be taken as true.

The results of analysis of the field data are summarized in table 46.1.

Table 46.1. Results of analysis of repeated measurements

Particulars	Type of Unit							
	.04		.06		.08		.10	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
No. of units	29	29	18	18	16	16	13	13
Average no. of trees	8.72	9.34	11.67	11.06	17.88	18.38	20.00	18.00
Variance	18.99	18.38	57.18	51.23	57.45	61.85	93.17	68.33
CV%	49.95	45.87	64.81	64.74	42.80	42.80	48.26	45.92
t – Statistics	2.34**		0.75		1.05		2.11	
$(E_2 - E_1)$ /A	+15.5		-10.2		+6.3		-20.0	

** - singnificant at the 5% level
E_1 , E_2 - enumeration 1, enumeration 2, respectively
A - area of subplot, ha.

A seen in the above table, coefficients of variation in plot total number of trees range between 42.40% to 64.81% both inclusive. The .06 unit has the highest CV% with 64.81 and 64.74 respectively for the first and the second enumeration, while the .08 unit has the least CV% with 42.40 and 42.80 respectively for the first and the second measurement.

The difference in the estimates of number of trees is significant at the 5% leval for .04 unit only.

For a one-hectare sample, tree number was underestimated by 15.5 trees with .04 unit, overestimated by 10.2 trees with .06 unit, underestimated by 6.3 trees with .08 unit, and overestimated by 20 trees with .10 unit on the average.

Thus, subplot type .08 again seemed to be the best among those unit types that had been experimented with.

5. Conclusion

A sampling unit for the NFI system is, as aforesaid, made up of a cluster of subplots. As such optimization of the sampling unit will be affected by shape, size, number and arrangement of subplots.

Generally, ease of establishment and length of perimeter decide the shape of the plot. Circular plots have both of these cirteria in that the perimeter can be defined with a single measurement, radius, and the perimeter has the shortest length compared to other plot shapes. Circular subplots had therefore been the choice in the present study.

In connection with the size of the subplot, five subplot types were tried. They were .04, .05, .06, .08 and .10 ha. As a matter of fact, the last two types had been the attraction, since it was desired to apply as big a subplot as possible. We would like to test whether it was practicable, convenient, and relatively free of bias in locating border-line trees if circular plots of that big were used in tropical forests with dense undergrowth on difficult terrain.

Big size subplots are necessary especially for the permanent sample plots, because the bigger the subplot size, the fewer will be the number of the elements, the centre posts, and other permanent demarcations the establishment of which are time – consuming.

The experience of the crew leaders indicated that .10 ha was too big. Crew leaders preferred either .06 or .08 ha subplots.

Statistical analysis of the field data have now show the superiority of .08 ha-unit among those tested. It was most efficient and thus optimum. In addition, it had the least tree location errors, and the least CV%. In the light of these results of statistical analysis, and the experience of the crew leaders, the suplot type .08 is considered most appropriate for the NFI system, although subplot types .07 and .06 could also be acceptable.

References

1. Cochran, W. G. (1963) Sampling techniques. John Wiley and Sons, Inc., New York.
2. Cunia, T (1973) Dummy variables and some of their uses in regression analysis, proceedings of the June, 1973 Meeting of IUFRO Subject Group 84.02, Vol.1: Cunia, Kuusela and Nash (editors), SUNY College of Environmental Science and forestry, Syracuse, N.Y.
3. Kyaw Tint (1980) Field Instructions for the National Forest Inventory of Burma, Forest Dept., Burma.