TECHNICAL REPORT No. 3(1)

PREINVESTMENT SURVEY OF FOREST RESOURCES

EAST GODAVARI (A. P.)

DATA PROCESSING

सत्यमेव जयते

GOVT. OF INDIA
MINISTRY OF AGRICULTURE
NEW DELHI
1972

Contents

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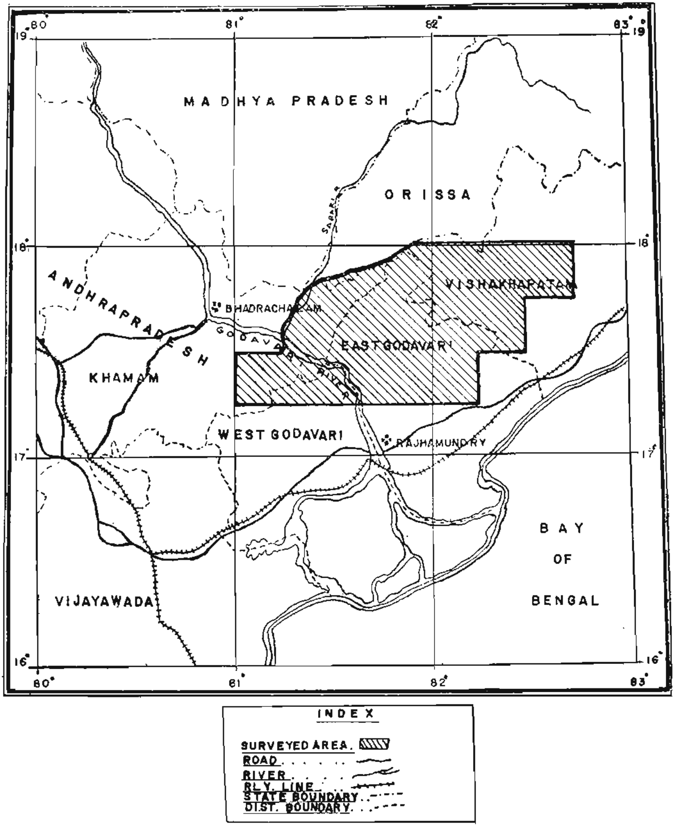
MAP SHOWING THE LOCATION OF SURVEYED AREA OF EAST GODAVARI. (A. P.)

SCALE : 1 INCH = 32 MILES



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1. INTRODUCTION

In the year 1970 the Project "Preinvestment Survey of Forest Resources" carried out an integrated survey of forest resources lying in the East Godavari Catchment of Andhra Pradesh with a view to determine the forestry and forest industries development potentialities in the region. Present report describes salient features related to data processing and forms a technical annex to the main report.

There are three broad components of any data processing system as shown below in form of a block diagram.

Input is specified by data set, crew which collects the data and the sampling design. This is described in Chapter 2.

System includes all data processing operations starting from input to production of final tables and other results. This is described in Chapter 3.

Statistical methods for estimation of parameter values are given in Chapter 4. This Chapter also gives relative precision for various alternatives to design the survey.

Output includes all final products from data processing system. They may be in form of computer print output, punched cards, data files on disk or tape. All intermediate outputs are described in Chapter 3 and all final output in Chapter 5.

Processing of Bamboo data is described in Chapter 6.

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The data has been processed using IBM/1620 Model II Computer of Planning Commission. This computer has following characteristics:

(a) Memory 40 K characters

(b) One Card Reader

(c) One Line Printer

(d) 3 Disks as peripheral devices.

Present report aims at covering only the important details. Actual operations involved are much more. Should there by any need for further explanation, the Project will be glad to furnish the same. All enquiries should be addressed to Chief Coordinator, Preinvestment Survey of Forest Resources, C-4/16, Safdarjung Development Area, New Delhi-16.

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2. DESCRIPTION OF INPUT

2.1 COLLECTION OF DATA

For collecting the data a post-stratified systematic sampling design was used. Various stages of work are described below:

2.1.1 Stratification

On photos of scale 1:60,000 taken in February, 1968 following broad land use and forest strata were delineated. An area of 10 ha. was accepted as minimum unit for delineation on aerial photographs. The interpreted details were transferred on base map and areas of different strata were obtained by dot grid method therefrom with one dot representing 1 ha.

Land use	Stratum name	Code	Area in ha.
Forest	Low volume Medium volume High volume Plantation	1 2 3 4	122,709 212,893 319,159 7,467
Shifting Cultivation	Shifting Cultivation	5	60,456
Permanent Cultivation and habitation	Cultivation	6	268,799
Blank	Blank	7	41,323
Water	Water	8	8,806
Total			1,041,612

2.1.2 Systematic Cluster Sampling

The survey area was divided into regular grids of 2½' longitude and 2½' latitude. In each grid a cluster of two plots was systematically laid out with centre of plot No.1 coinciding with the grid centre and centre of plot No.2 located 400 m. eastwards from the centre of the first plot.

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Both plots were square in shape with an area of 0.1 ha. each, resulting in sampling intensity of about 0.01%.

Field parties visited only those ground samples which had either been classified as forested with help of photointerpretation or were lying in the transition area of forest and other landuse class.

On each plot information was collected in following Field Forms:

(a) Plot Description: It contains all important qualitative information about the plot. Minimum area unit for plot classification information was fixed as 2 ha.

(b) Plot Enumeration: It contains diameter measurement by species for all trees in the plot more than or equal to 10 cm. diameter at breast height (1.37 m.)

(c) Bamboo Enumeration: It contains both qualitative as well as quantitative information about bamboo in the plot.

(d) Sample Tree: It contains information about dominance, height, clear bole, form and defect. Trees from 10 cm. to 40 cm. are measured on 1/8th quadrant of every plot whereas trees more than 40 cm. all over the plot.

2.1.3 Special Study

(a) Form and Cull Study: Fellings were done on a systematic basis to determine volume form and cull. For this purpose a portion of inventoried samples were selected systematically with a random start. Intensity of felling works out to be about 0.001% by area.

(b) Bamboo Weight Data: This information was collected simultaneously while collecting felled tree data. In each plot a maximum number of 10 culms were felled for study of air dry weight.

Lay out of field forms is given in Enclosure-I. Details regarding coding system are given in the field manual which may be referred to if necessary.

2.1.4 Post Stratification

The ground plot lay out was superimposed on photointerpretation map. Each ground plot was stratified into one of the strata depending on the stand class in which plot centre was located.

2.2 PREPARATION OF INPUT

2.2.1 Documentation of Field Data

All field forms were properly documented. Existence of all forms was checked with reference to the master list of samples. Total number of forms available in Data Processing Unit are:

Form Type	No. of sheets
Plot Description	512
Plot Enumeration	725
Bamboo Enumeration	335
Sample tree	646
Form Factor	1358

All forms were checked manually for validity of codes used in various columns of information. Missing information was coded afresh in consultation with the crew members.

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2.2.2 Unit Record Operations

Field data was punched on cards and verified. Total number of cards are:

Card deck	Field Sheet	Job code (col.1-3)	Card design (col.4-5)	Total No. of cards
1	Plot Description	198	01	1024
2	Plot Enumeration	198	02	2801
3	Bamboo Enumeration	198	03	1234
4	Sample Tree	198	04	1956
5	Form Factor Data	198	06	14456

There was no card design 05 in the survey.

Punched cards were sorted and collated. Sort keys are given in Enclosure-II. The sorting order was subsequently checked with help of a collator.

2.2.3 Computer Editing

Punched card data was thoroughly edited with help of computer programmes. For each card design separate programmes were developed. In general, programmes were designed for:

(a) Card Accounting: The number of cards at different levels of hierarchy was cumulated e.g. by quarter inch sheet, grid No. etc. The cumulated values were checked against expected total.

(b) Checking Validity of Codes: For each field a list of possible codes was fed. The actual value of an item in a particular record was checked against the standard codes.

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(c) Checking logical consistency in various fields of a card: Within each card logical inter-relationship between/among various fields was defined. The actual values were then compared against the standard relationship.

(d) Logical inter-relation between records of same card design: This is of some importance in case of form factor data where diameter measurements at various sections along the stem are inter-related. Diameter measurement at particular section was compared with measurements on preceding and succeeding sections.

(e) Logical inter-relation between various card designs of the same sampling unit: Normally a forested sample unless its forest type is blank or it is inaccessible should have full set of all forms including plot enumeration, sample tree etc. Keeping this in view all data for each sampling unit was checked for consistency.

(f) Regression check on computed volume of form factor data: Based on computed value of volume of individual trees regression equation was developed correlating diameter and height of all trees with their measured volume. Residuals were computed for each tree. Trees having high residual (more than 60%) of expected volume were scrutinised in great detail with help of basic field data. Four highly abnormal trees were discovered which were excluded from the volume table construction as they were found to have abnormal development of diameter and height.

(g) Photo Checks: Photo and ground informations for the common data were carefully compared. In case of few plots some discrepancy was found for which plot data was studied together with information from aerial photographs. Keeping both in view a decision on the final code was made.

2.3 CORRECTION OF DATA

Corrections were made only where probability of error was rated very high. Always in consultation with field officers inconsistencies, logical or otherwise were rectified. In such cases data was written afresh on coding sheet, punched on cards and verified. Simultaneous corrections were made in all related data files viz:

a) Field Forms

b) Punched Card Deck

c) Disk File

d) Computer Print Output

The correction operation was performed exercising utmost care. All errors and corrections have also been properly documented for guidance in future.

3. SYSTEM DESIGN

From editing of field data to printing of final tables a series of data processing activities are involved. In this series following major links can be identified:

(a) Calculation of tree volume from felled tree data.

(b) Trials for general volume equation.

(c) Trials for local volume equation.

(d) Calculation of individual tree volume from enumeration data.

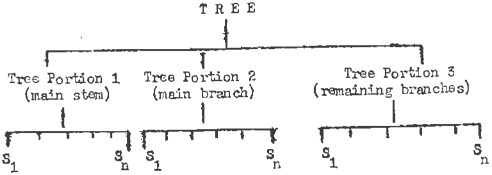
(e) Processing of plot volume summary.

(f) Processing of tables and error calculations.

(g) Following Note presents a brief outline on these operations.

3.1 TREE VOLUME COMPUTATION

Volume of a tree has been distinguished into three tree portions:



In this diagram S denotes a section. Each tree portion was sectioned into one metre lengths. At ends of each section diameter overbark, underbark, length and width of defect were recorded.

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For computing volume (V) of a section, Smalian formula was used:

$$V = \frac{\pi}{4} \frac{d_1^2 + d_2^2}{2} l$$

where d_1 and d_2 are diameter measurements at two ends of a section, l is its length, π is a constant and V is volume. For overbark volume d_1 and d_2 are given overbark and for underbark volume d_1 and d_2 are underbark.

Defective areas at lower and upper sectional ends were calculated by using rectangular formulae -

Defect area = Length of defect x Width of defect.

If there was no defect at a section, defect area was taken as zero. Defect volume was calculated by formula:

$$\text{Defect volume} = \frac{A_1 + A_2}{2} l$$

where A_1 and A_2 are defect areas at two ends of a section and l is the length of the section.

For each section three types of volume were calculated:

1. Volume over bark
2. Volume under bark
3. Cull Volume.

Above tree volumes were cumulated over each tree portion separately. Thus in all 9 types of volumes were generated for each tree:

OVERBARK			OVERBARK			OVERBARK		
Tree Portion 1	Tree Portion 2	Tree Portion 3	Tree Portion 1	Tree Portion 2	Tree Portion 3	Tree Portion 1	Tree Portion 2	Tree Portion 3

Form Factor data is available in volume table data file on punched cards for further processing. Its layout is given in Enclosure-III.

The design for form factor work for the entire East Godavari survey yielded following number of trees by species:-

S.No.	Species name	Species code	No. of trees
1.	Terminalia tomentosa	003	60
2.	Pterocarpus marsupium	004	41
3.	Anogeissus latifolia	009	58
4.	Lagerstroemia parviflora	012	21
5.	Xylia xylocarpa	016	113
6.	Terminalia chebula	030	20
7.	Buchanania lanzana and latifolia + anugustifolia	042	27
8.	Grewia tiliaefolia	060	52
9.	Rest of the species	All other codes	353
	Total No. of trees		745

3.2 TRIALS FOR GENERAL VOLUME EQUATIONS

It was decided in advance that separate equations will be developed for a species only if number of observations for this exceed 20. Main idea behind these trials was to discover the variation in form between species. For this purpose simple equation of type $V = a + b\ D^2H$ was tried by species, where V is volume underbark of the main stem in cubic metres, D is breast height diameter in metres and H is total height in metres. The values obtained are summarised below:

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Volume Equation $V = a + b\ D^2H$

Sl. No.	Sp. code	No. of obs	Mean V m^3	SD V m^3	Mean D^2H m^3	SD D^2H m^3	Regression Equation Constant	Coeff.	Mean Square residual	R^2
1.	03	60	.250	.278	.973	1.215	0.052	0.203	.0170	0.787
2.	04	41	.320	.393	1.160	1.420	0.005	0.272	.0061	0.962
3.	09	58	.243	.264	.970	1.173	0.033	0.216	.0056	0.923
4.	12	21	.171	.141	.597	0.484	0.016	0.280	.0045	0.795
5.	16	113	.211	.344	.833	1.379	0.018	0.232	.0160	0.867
6.	30	20	.148	.210	.457	0.503	-0.040	0.412	.0014	0.970
7.	42	27	.084	.157	.286	0.603	0.011	0.256	.0007	0.972
8.	60	52	.086	.078	.318	0.296	0.005	0.252	.0006	0.909

Linear equations were plotted on a graph. Species having similar linear equation were grouped together as follows:

Group No.	Species names	Code
1	Terminalia tomentosa	003
	Anogeissus latifolia	009
	Xylia xylocarpa	016
2	Pterocarpus marsupium	.004
	Lagerstroemia parviflora	012
	Terminalia chebula	030
	Buchanania lanzana and latifolia + anugustifolia	042
	Grewia tiliaefolia	060
3	Rest of the species	All other codes

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For each of above groups, following equations were tried:-

a) $V = a + b\,D^2H$

b) $V = a + b\,D^2H + c\,(D^2H)^2$

c) $V = a + bD^2 + cH + d\,D^2H$

d) $\frac{V}{D^2H} = a + \frac{b}{D^2H}$

Following information was also printed for each tree in addition to normal output of the programme.

a) Observed value for volume (0)

b) Calculated value for volume (e)

c) Difference of these two

d) $\frac{\sum (0 - e)^2}{n}$ where n stands for the number of observations.

Above equations were separately processed for each of following volume types:

a) Total volume underbark (Tree portions 1, 2 and 3 combined)

b) Main stem volume underbark (Tree portions 1 and 2 combined)

c) Clearbole volume underbark (Tree portion 1)

Keeping in view values of R^2, standard error and bias in estimating volume by diameter classes, best equation was selected for each species group. Details about selected equation are given below for the character - Total volume of the tree under bark.

a) Species Group 1.

No. of observations = 229.

Volume Equation selected for diameter $\leq$ 30 cms.

$$\frac{V}{D^2H} = .340 + \frac{.001}{D^2H}$$

Volume Equation selected for diameter ≯ 30 cms.

$V = .023 + .306\ D^2H$

b) Species Group II

No. of observations = 161.

Volume Equation selected for all diameter classes

$V = .006 + .328\ D^2H$

c) Species Group III

No. of observations = 353

Volume Equation selected for all diameter classes

$V = .001 + .333\ D^2H$

3.3 TRIALS FOR LOCAL VOLUME EQUATIONS

Equations obtained from previous trials were used for estimating volume of sample trees. Output is summarised in sample tree data file given in Enclosure-IV. This file is very important as it contains a variety of information for each sample tree like diameter, height, clear bole length, assessment of external defect, straightness, estimated volume etc.

Number of sample trees available by species with more than 30 observations are as under:

Species	Code	No. of trees
Tectona grandis	001	60
Terminalia tomentosa	003	290
Pterocarpus marsupium	004	194
Ougenia dalbergioides	006	56
Diospyros melanoxylon	007	72

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Species	Code	No. of trees
Bridelia squemosa + retusa	008	50
Anogeissus latifolia	009	306
Emblica officinalis	010	90
Chloroxylon swietenia	011	50
Lagerstroemia parviflora	012	78
Syzigium cuminii	014	93
Xylia xylocarpa	016	438
Mangifera indica	017	45
Lannea grandis	020	105
Garuga pinnata	021	70
Schleichera trijuga + oleosa	024	52
Madhuca latifolia	025	53
Terminalia belerica	026	44
Adina cordifolia	027	35
Mitragyna parviflora	028	31
Terminalia chebula	030	74
Buchanania lanzana and latifolia + anugustifolia	042	54
Dalbergia paniculata	050	44
Dillenia pentagyna	052	77
Grewia tiliaefolia	060	94
Cleistanthus collinus	063	80
Stereospermum suaveolens + xylocarpum	074	39
Tamarindus indica	076	42
Rest of the species		827
Total		3543

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Keeping in view results obtained from general volume equation trials species were grouped together as done earlier.

Following equations were tried:

a) $V = a + bD + cD^2$

b) $\frac{V}{D^2} = \frac{a}{D^2} + \frac{b}{D} + c$

c) $\sqrt{V} = a + bD$

d) $\text{Log } V = a + b \text{ Log } D.$

Above equations were separately processed for following volume types:

1. Total volume under bark (Tree portion 1, 2 and 3 combined)
2. Main stem volume under bark (Tree portion 1 and 2 combined)
3. Clear bole volume under bark (Tree portion 1)

Based on values of R^2, standard error and bias in estimating volume for various diameter classes best equation was selected for each group. The details of the equation selected for the character - Total volume under bark are as given below:-

a) Species Group I

No. of observations = 1034.

Local volume equation selected for diameter < 30 cms.

$\text{Log } V = 2.3424 + 2.4970 \text{ Log } D$

Local volume equation selected for diameter > 30 cms:

$\text{Log } V = 1.9902 + 2.2111 \text{ Log } D$

b) Species Group II

No. of observations = 494

Local volume equation selected for all diameter classes:

$\text{Log } V = 2.2491 + 2.5206 \text{ Log } D$

c) Species Group III

No. of observations = 2015

Local volume equation selected for all diameter classes:

$$\text{Log } V = 2.1795 + 2.5045 \text{ Log } D$$

3.4 TREE VOLUME PREDICTION

With the help of final local volume equations, volume of trees in plot enumeration card was computed and results stored in tree volume file whose layout is given in Enclosure V. This file serves the basis for compilation of all stand and stock tables.

3.5 PLOT VOLUME COMPILATION

From Tree volume file, plot summary file is prepared whose layout is given in Enclosure VI. This file forms the basis for calculation of sampling error, related area and volume per ha. estimation from ground sampling.

3.6 TABULATION AND ERROR CALCULATION

Details regarding tabulation and error calculation are given in Chapter 5.

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4. STATISTICAL METHOD

4.1 ANALYTICAL PROCEDURE

Design of sample survey has already been described in Chapter 2 which may be referred if necessary before going further.

Calculation of sample estimates and their errors in case of systematic sampling is a controversial issue. A separate technical note on this subject has been prepared which may be referred if necessary.

For analysing the field data, based on systematic cluster sampling, method of ratio estimates has been used assuming a simple random distribution. It may be noted that this method tends to over-estimate the sampling error (see bibliography).

The present data can be analysed in various ways using suitable combinations of ground and photo informations. The options are:

(1) Unstratified Sampling:

  (a) Both area and volume information obtained from ground sampling alone.

  (b) Volume information obtained from ground sampling and ~~area~~ information from aerial photographs.

(2) Stratified Sampling (Post Stratification):

  (a) Stratum area and volume information obtained from ground sampling alone.

  (b) Stratum area information obtained from photointerpretation and volume information from ground sampling.

The project has adopted results given by method 2(b) as final.

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4.2. FORMULAE USED

4.2.1 Unstratified Sampling using Ground Informations alone:

A cluster of two plots is considered as one sampling unit. Let n be the number of sampling units measured in the field. Let z_i denotes total area of the i-th sampling unit (in this case it is always equal to 0.2 ha.). Let y_i and x_i denote the contribution to volume and forest area respectively by the i-th sampling unit. Then v - the estimated volume per ha. is

$$v = \frac{\Sigma y_i}{\Sigma x_i} \qquad (1)$$

The standard error percent (S_1) of volume per ha. is:

$$S_1\% = \frac{100}{v}\sqrt{\frac{(\Sigma y_i^2 - 2v \Sigma y_i x_i + v^2 \Sigma x_i^2)}{(\Sigma x_i)^2}} \quad .. \qquad (2)$$

In this formula finite population correction has been ignored.

The percentage forest area is estimated from the formula

$$a = \frac{\Sigma x_i}{\Sigma z_i} \times 100 \quad .. \quad .. \qquad (3)$$

The total forest area (F) is estimated by multiplying the percentage of forest area as estimated above with the total survey area(A).

$$F = \frac{a \times A}{100} \quad .. \quad .. \qquad (4)$$

The total survey area is assumed to be free of any sampling error. Thus the percentage sampling error in estimating total forest area (F) is same as that of percentage forest area (a).

The sampling error percent ($S_2\%$) for area ignoring finite population correction is given by:

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$$S_2\% = \frac{100}{a}\sqrt{\frac{\sum x_i^2 - 2a\sum x_i z_i + a^2 \sum z_i^2}{(\sum z_i)^2}} \qquad (5)$$

The total volume (V) in the forest area (F) is calculated by the formula

$$V = v \times F \quad .. \quad .. \qquad (6)$$

The percentage sampling error (S%) in estimating total volume is

$$S\% = \sqrt{(S_1\%)^2 + (S_2\%)^2} \quad .. \quad .. \qquad (7)$$

This formula (7) does not take into account the following two types of error:

(i) Sampling error due to volume table.

(ii) Non-sampling error.

4.2.2 Unstratified Sampling using Forest Area (F) information from Aerial Photographs and Volume/ha. (v) information from ground sampling:

By this method the total volume is determined by formula (6) above. Here also sampling error % (S_1%) in volume per ha. is calculated by the formula (2) given above. The percentage sampling error (S_2%) in estimating forest area is given by the formula

$$S_2\% = 100 \times \sqrt{\frac{(1 - a)}{a \times (N-1)}} \quad .. \quad .. \qquad (8)$$

where N is the total number of dots in the total survey area and a is the proportion of dots falling in the forest area.

The error in estimating total volume (V) in forest area (F) is calculated by formula (7) above viz;

$$S\% = \sqrt{(S_1\%)^2 + (S_2\%)^2}$$

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4.2.3 **Stratified Sampling (Post Stratification) based on Stratum Area and Volume/ha. information from Ground Data alone.**

(a) Calculation of error by stratum

The total volume in the stratum is estimated by

$$V_k = v_k \times F_k \quad \ldots \quad \ldots \quad (9)$$

where V_k = total volume in the k-th stratum

v_k = Vol./ha. in the stratum

F_k = Forest area in the stratum

All the formulae described in section 4.1.1 hold true if the word 'Forest' is substituted by the word 'Stratum' with following conventions:

A cluster is defined as effective with reference to a stratum if at least one of its plots fall in the stratum. For all effective clusters x_i, y_i and z_i are calculated as given below:

(i) If both plots of a cluster fall in the same stratum for the i-th sampling unit y_i and x_i are defined as in 4.1.1.

(ii) If one plot of the i-th cluster falls in k-th stratum but the second does not, then z_i, y_i and x_i are equal to volume and area of plot falling in the stratum - the contribution by the outside plot is taken as zero.

With above convention x_i, y_i and z_i are defined for all the effective clusters. Error in estimating volume/ha. and area can then be calculated using formulae given in 4.1.1.

(b) Calculation of Error Pooled over all strata

Normal formula for calculating the pooled error cannot be applied for the present survey because samples in various strata are not independently distributed. To overcome this problem a modification of Matern Method (1962) has been used for the present report.

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As before let z_i be the total area of i-th sampling unit out of which an area x_{ik} falls in the stratum k and has volume y_{ik}. For each sampling unit the summation - $\sum_k (y_{ik} - v_k x_{ik})$ and $\sum_k x_{ik}$ is built, where v_k is average volume per ha. in the stratum k. The percent sampling error in volume per ha. (finite population correction has been ignored) is given by

$$S_1\% = \frac{100}{v} \sqrt{\frac{\sum_i \left(\sum_k (y_{ik} - v_k x_{ik})\right)^2}{\left(\sum_i \sum_k x_{ik}\right)^2}} \quad .. \qquad (10)$$

where v volume/ha. is a weighted average of volume per ha. over all the strata. Symbolically

$$v = \frac{\sum F_k v_k}{\sum F_k} \quad .. \quad .. \qquad (11)$$

where F_k is forest area in stratum k.

The error in area estimation is obtained by formula

$$S^2\% = \frac{100}{a} \sqrt{\frac{\sum_i \left(\sum_k (x_{ik} - a_k z_{ik})\right)^2}{\left(\sum z_i\right)^2}} \quad .. \qquad (12)$$

where a_k is proportionate area under stratum k and a is proportionate area of total forest.

4.2.4 Stratified Sampling using Stratum Area from Photointerpretation and Volume/ha. by Stratum from Ground Sampling

(a) Calculations by Stratum

Error can be divided into two components.

(i) Error in area estimate.

(ii) Error in Volume/ha. estimate.

For calculating (i) formula given in section 4.2.2 holds true and for (ii) formula given in section 4.2.3(a) should be used.

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(b) Calculations for Pooled Data

An approach similar to that used in section 4.2.3(b) has been followed.

4.3. RELATIVE PRECISION OF SAMPLING PROCEDURES

There are two parameters which determine the relative efficiency of one survey method over another. They are - cost of survey and variance of estimates. Efficiency is inversely proportion to both of them. Thus for two surveys with costs C_1 and C_2 and variances S_1^2 and S_2^2 the relative efficiency of one over two (E_{12}) can be given by

$$E_{12} = \frac{C_2 \; S_2^2}{C_1 \; S_1^2} \quad .. \quad .. \quad (13)$$

From an analysis of present data S_1^2 and S_2^2 have been worked out. The values of C_1 and C_2, however, were not available at the time of writing this report. Therefore, value of ratio $\frac{S_2^2}{S_1^2}$ (relative precision) is only being given. It must be noted, however, that relative precision has to be multiplied with relative cost ratio $\frac{C_2}{C_1}$ for making any valid comparison.

4.3.1 Unstratified Sampling

Options 4.2.1 both area and volume information obtained from ground sampling compared with 4.2.2 volume information obtained from ground and area information obtained from photo. Here it should be borne in mind that in this option only total forest area and total volume in the whole of forest area is required without any break up at stratum level. The relative figures are given in table-1.

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Table 1

S.No.	Method	No. of grids tackled	Variance in estimating total vol.(%)	Relative precision
1.	Ground Sampling alone	512	18.25	0.92
2.	Ground Sampling supplemented with photointerpretation.	484	16.81	1

From this comparison it emerges out that at total forest area level main saving by use of aerial photointerpretation is accounted for by reduction in number of ground plots to be visited. For the present survey this reduction was of the order of 21%. So far as precision of estimates is concerned there is little difference between the two methods.

4.3.2 Stratified Sampling (Post Stratification)

Option 4.2.3 stratum area and volume information by strata obtained from ground sampling compared with 4.2.4 area information obtained from photointerpretation and volume information from ground plots (latter method has been used in the present report).

~~Table 2 gives necessary~~ information about sampling error in estimating volume/ha. and area by strata.

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Table 2 - Mean and Standard Error for Important Strata

Stratum	GROUND SURVEY RESULTS					PHOTOINTERPRETATION RESULTS					Relative precision
	Area		Vol./ha.		Total	Area		Vol./ha. *		Total	
	Mean (% of total)	SE%	Mean m^3	SE%	SE%	Mean (% of total)	SE%	Mean m^3	SE%	SE%	
1	2	3	4	5	6	7	8	9	10	11	12
1. High Volume	32.4	6.4	98.6	3.9	7.5	30.6	0.14	98.6	3.9	3.9	.27
2. Medium Volume	19.9	8.4	70.9	5.1	9.8	20.4	0.19	70.9	5.1	5.1	.26
3. Low Volume	12.2	10.4	48.3	7.1	12.6	11.8	0.27	48.3	7.1	7.1	.31
4. Shifting Cultiv.	5.1	17.8	19.0	24.4	30.2	5.8	0.39	19.0	24.4	24.4	.65

In reality no stratification by volume class was done on the ground. Above results for ground data alone have been calculated assuming that field crew would have done the same stratification as was done by photo-interpretation crew. This is not strictly true. Normally ground stratification should result in less variance for volume per hectare than that of photointerpretation. However, the main point brought out by above table is high variance in estimating stratum area by ground sampling. For ground survey alone errors associated with area are much higher compared to that of volume/ha. A lesser variance in estimating volume per hectare would not substantially alter the precision of total volume estimate. The main contribution of photointerpretation lies in making error in area estimation very small. Following important fact emerges from above data.

* Note: The values quoted here are taken from ground data, therefore, col.4 is identical to 9 and 5 to 10.

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Stratification from ground data may result in less variance so far as estimation of volume/ha. by strata is concerned, but estimation of area is associated with high variance. Therefore, estimation of total volume by strata from ground data alone is subject to high sampling error. If ground sampling is supplemented with photointerpretation significant gains are obtained.

Bibliography

i) Cochran, W.G. (1946) Relative accuracy of systematic and stratified random samples for a certain class of population. Ann. Math. Stat. 17, 164-177

ii) Finney, D.J. (1948) Random and Systematic sampling in timber surveys. Forestry 22, 1-36.

iii) Finney, D.J. (1950) An example of periodic variation in forest sampling. Forestry 23, 96-111.

iv) Matern, Bertil (1962) Estimating the Standard Error in stratified sampling with systematic sampling inside strata.

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5. DESCRIPTION OF OUTPUT

5.1. PLAN OF TABULATION

Source file for tabulation were as under:

(1) Plot Summary File

(2) Tree Volume File

(3) Bamboo Summary File

Correspondingly tables processed can be divided into 3 categories:

(1) Plot related information

(2) Stand and Stock related information

(3) Bamboo information

Important tables are being reproduced in part II of the report.

5.2. RELATIONSHIP BETWEEN TOTAL VOLUME AND OTHER TYPES OF VOLUME

Volume figures reported in part II of the report stand for "total volume of a tree underbark including branchwood till 5 cm. top diameter limit overbark."

Conversion factor for calculating other types of volume viz. volume of clear bole, main stem (clear bole + leading branch) and branch volume all underbark are given below:

Conversion factors for other volume types

Diameter Class cm.	Conversion factor for volume of		
	Clear bole	Main stem (clear bole+leading branch)	Branchwood (including leading branch
≤ 10 < 20	0.86	0.91	0.14
≤ 20 < 30	0.65	0.82	0.35
≤ 30 < 40	0.55	0.76	0.45
≤ 40 < 50	0.52	0.74	0.46
50 +	0.51	0.73	0.49

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5.3. CULL VOLUME

An analysis of data indicated that percentage of cull occurring in the trees is negligible for all species. Therefore, no separate tables have been processed for character "Net Volume."

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BAMBOO DATA PROCESSING

6.1. CULM DATA PROCESSING

The source document for this step was Bamboo Enumeration Form. The data was punched, verified and sorted by species.

A cumulative total was then obtained by size and quality class by species for the following characters:

S.No.	Character
1.	Current Season's culms
2.	Two season's culms
3.	Culms of three seasons and more
4.	Total number of culms
5.	Damaged or top broken culms
6.	Dry scarred or rotten culms
7.	Rest culms
8.	Total length
9.	Length upto 2 cms.
10.	Culm diameter
11.	Total No. of clumps measured for above characters.

Data cumulated in the tables 1-10 given above are divided cell-wise by the corresponding number of clumps (table 11) to get the figures on per clump basis.

6.2. CULM WEIGHT PROCESSING:

Equations used for predicting weight of a culm was $W = 1.0869 + 0.0146\ D^2H$. where H is total height of a culm in metres, D is diameter of a culm at breast height in cm., and W is weight of a culm in Kg. By applying these equations to table numbers 1 and 2

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(which give average diameter and average height of a culm by size and quality class) one gets corresponding weights for a culm.

6.3. CLUMP WEIGHT PROCESSING

Culm weight data when applied to tables 5-7 (which give number of damaged or top broken and dry scarred or rotten and rest culms per clump by site and size class) one gets weight data for a clump. Instead of giving equal weight to sound and damaged or broken culms occurring in the clump, the following method of weightage was used to get realistic figures for commercial weight of a clump.

a) For sound culms use actual weight as calculated above.

b) For damaged or top broken culms multiply the weight by ½.

c) For dry scarred or rotten culms weight is equal to 0.

6.4. PREPARATION OF BAMBOO SUMMARY FILE

With help of information processed in step-1 (culms per clump information) and step-3 (weight of a clump) following data is compiled for each plot.

a) Clump enumeration by size classes.

b) Total weight of all culms on the plot.

c) The weight of rest culms on the plot.

d) Weight of the damaged or top broken culms on the plot.

e) Total No. of current season's culms.

f) Total No. of two season's culms.

g) Total No. of three season's culms.

The file has additional informations regarding occurrence, quality, regeneration and flowering which are transferred from Bamboo Enumeration Card.

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6.5. PROCESSING OF TABLES

In addition to input tables mentioned earlier following tables are processed from above data file by bamboo occurrence and site class.

a) No. of Plots

b) Area

c) Area (%)

d) No. of clumps/ha.

e) Total No. of clumps

f) Bamboo Clump Weight/ha.

g) Bamboo Clump Weight.

h) Distribution of Bamboo Weight (%)

i) No. of current season's culms/ha.

j) No. of two season's culms/ha.

k) No. of three season's culms/ha.

l) Total No. of culms/ha.

LAY OUT OF DATA ON CARD DESIGN OF TC 16 EAST GODAVARI

CUSTOMER NAME

TYPE OF CARD	Fields (left to right)
1. CD 01	JOB NO; CARD DESIGN; RI PORT NO; SUB R NO; CREW LEADER; STATE; REVENUE DISTRICT; FOREST DIVISION; LAND CLASS; LEG STATUS; ALTITUDE; TOPOGRAPHY; SLOPE; POS ON SLOPE; ASPECT; STONINESS; HUMUS; COLOUR; CONSISTENCY; TEXTURE; DEPTH; VEGETATION; ORI OF STAND; FOREST TYPE; NO OF STOREYS; TOP HT; SIZE CLASS; STOCKING %; REGEN; OCCURANCE; SPECIES; QUALITY; REGEN; BIOTIC INFL; PAST TREAT; PROB TREAT; GRASS INCID; FIRE INCID; PLOT NO; GRID NO; QR INCH SHEET; INVENTORY DESIGN
2. CD 02	JOB NO; CARD DESIGN; REPORT NO; S R NO; SPECIES CODE; DIAM; SPECIES CODE; DIAM; SPECIES CODE; DIAM; SPECIES CODE; DIAM; SPECIES CODE; DIAM; SPECIES CODE; DIAM; SPECIES CODE; DIAM; SPECIES CODE; DIAM; SPECIES CODE; DIAM; TOTAL NO OF TREES IN PLOT; PLOT NO; GRID NO; QR INCH SHEET; INVENTORY DESIGN
3. CD 03	JOB NO; CARD DESIGN; R NO; S R NO; CREW LEADER; BLANK; OCCURANCE; SPECIES; QUALITY; REGN; FLOWERING; CLUMP SIZE CLASS I M; CLUMP SIZE CLASS I-2 M; CLUMP SIZE CLASS 2+M; CLUMP NO; SIZE CLASS; SPECIES CODE; NO OF CULMS; TWO SEASON; THREE SEASON & MORE; TOT NO OF CULMS; DEAD; DRY SEASONED; REST; AV TOT LENGTH IN M; AV LENGTH UPTO 2 CM DIAM; AV CULM DIAM IN CMS; HOLLOWNESS; TOTAL NO OF CLUMPS; PLOT NO; GRID NO; QR INCH SHEET; INVENTORY DESIGN
4. CD 04	JOB NO; CARD DESIGN; R NO; S R NO; S NO; SPECIES CODE; DOMINANCE; D B H; D B T; TOTAL HEIGHT; CLEAR BOLE; FORM LONGIT; FORM SECT; DEF NAT; DEF OTHERS; S NO; SPECIES; DOMINANCE; D B H; D B T; TOTAL HEIGHT; CLEAR BOLE; FORM LONGIT; FORM SECT; DEF NATURAL; DEF OTHERS; TOTAL NO OF TREES; PLOT NO; GRID NO; MAP SHEET NO; INVENTORY DESIGN
5.	
6. CD 06	JOB NO; CARD DESIGN; SL NO OF THE TREE; SPECIES CODE; TREE PORTION; SECTION; DIAM AT BOL OF EACH TREE O B; DIAM U B; DIAM OVER BARK; DIAM UNDER BARK; CULL ST CODE; TYPE OF DEFECT; DEFECT MEASUREMENT; DEFECT MEASUREMENT; TYPE OF DEFECT; DEF MEASUREMENT; DEFECT MEASUREMENT; TYPE OF DEFECT; DEFECT MEASUREMENT; DEFECT MEASUREMENT; SHAPE LONG; SHAPE SECT; BEFORE FELLING D B H O B; TOTAL HT IN M; BEFORE FELLING TOTAL HT IN M; HT OF THE STUMP; MID DIAM OF THE STUMP; STUDY TYPE; PLOT NO; GRID NO; MAP SHEET NO; INVENTORY DESIGN

PREPARED BY [signatures]

DATE PREPARED

ENCLOSURE - II

SORTING ORDER

PLOT DESCRIPTION (01)	(Major	75-78	Map Sheet
	(Inter	71-74	Grid
	(Minor	69-70	Plot
PLOT ENUMERATION (02)	(Major	75-78	Map Sheet
	(Inter	71-74	Grid
	(Minor	69-70	Plot
BAMBOO ENUMERATION (03)	(Major	28-29	Species
	(Sub Major	75-78	Map-Sheet
	(Inter	71-74	Grid
	(Minor	69-70	Plot
	(Sub Minor	25-26	Clump Number
SAMPLE TREE FORM (04)	(Major	75-78	Map Sheet
	(Inter	71-74	Grid
	(Minor	69-70	Plot
	(Sub Minor	9-10	Serial No. of Tree
FORM FACTOR DATA (06)	(Super Major	8-10	Species
	(Major	75-78	Mapsheet
	(Sub Major	71-74	Grid
	(Inter	69-70	Plot
	(Sub Inter	6-7	Sl. No. of Tree
	(Minor	11-12	Tree Portion
	(Sub Minor	13-14	Section No.

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ENCLOSURE - III

LAY OUT OF VOLUME TABLE DATA FILE

Though volume table data file was created on disk after finalising the general volume equations, the data was punched on to cards. Card layout for this file is as under:

Sl.No.	Card Cols.	Description
1.	1	Type of the card (Always 1 or 2)
2.	2	Map Sheet Code (1 for 8117 and 2 for 8217)
3.	3-6	Grid No.
4.	7	Plot No.
5.	8-9	Serial No. of the tree in the plot.
6.	10-12	Species Code
7.	13-16	Diameter in cm. with one decimal place.
8.	17-18	Total height in metres.
9.	19-20	Clear bole in metres.
10.	21-80	Six types of volumes punched in the format E 10.4

The six volumes are as under for card type 1 (punched in col.1 of the card);

1. Total volume under bark (Tree portions 1 + 2 + 3)
2. Total volume over bark (Tree portions 1 + 2 + 3)
3. Clear bole volume under bark (Tree portion 1)
4. Clear bole volume over bark (Tree portion 1)
5. Tree portion 2 volume under bark.
6. Tree portion 2 volume over bark.

and for the card type 2 (punched in col.1 of the card) they are:

1. Tree portion 3 volume under bark.
2. Tree portion 3 volume over bark.
3. Total cull volume (Tree portions 1 + 2 + 3)
4. Cull volume of tree portion 1
5. Cull volume of tree portion 2
6. Cull volume of tree portion 3

ENCLOSURE - IV

LAY OUT OF SAMPLE TREE DATA FILE

For this file print output is only available. For each of sample tree following information is recorded:

1. Serial No. of tree
2. Species Code
3. Dominance
4. D.B.H. (metres)
5. D.B.T. (cm.)
6. Total Height (metres)
7. Clear bole (metres)
8. Form Longitudinal
9. Form Sectional
10. Defect natural
11. Defect others
12. Total No. of trees in the plot.
13. Plot No.
14. Grid No.
15. Map Sheet
16. Inventory Design

17.	Volume underbark (Tree portion 1 + 2)	Calculated by the general equation $V = a + b\ D^2H$
18.	Volume underbark (Tree portion 1+2+3)	
19.	Volume underbark (Tree portion 1)	
20.	Volume underbark (Tree portion 3)	
21.	Net volume (Tree portion 1+2+3)	
22.	Net volume (Tree portion 1)	

23. Volume underbark (Tree portion 1+2)
24. Volume underbark (Tree portion 1+2+3)
25. Volume underbark (Tree portion 1)
26. Volume underbark (Tree portion 3)
27. Net volume (Tree portion 1+2+3)
28. Net volume (Tree portion 1)

) Calculated by the equation – $V = a + b\,D^2H$ for the particular species group.

29. Volume underbark (Tree portion 1+2)
30. Volume underbark (Tree portion 1+2+3)
31. Volume underbark (Tree portion 1)
32. Volume underbark (Tree portion 3)
33. Net volume (Tree portions 1+2+3)
34. Net volume (Tree portion 1)

) Calculated by the equation – $\frac{V}{D^2H} = a + \frac{b}{D^2H}$ for the particular species group.

35. Volume underbark (Tree portion 1+2)
36. Volume underbark (Tree portion 1+2+3)
37. Volume underbark (Tree portion 1)
38. Volume underbark (Tree portion 3)
39. Net volume (Tree portions 1+2+3)
40. Net volume (Tree portion 1)

) Calculated by the equation – $V = a + bD + cD^2$ for the particular species group.

41. Species group code.

A programme with all necessary input is available in documentation section which can generate this file on disk if required.

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ENCLOSURE - V

LAY OUT OF TREE VOLUME FILE

Volumes of enumeration trees is stored on disk in the following way:

Each record consists of one sector of 25 fixed point items and can accommodate information about three trees. Tree volume in cubic metre is multiplied by 1000 and is converted into fixed point mode.

Item No.	Description
1.	∠First Tree on the card ∠ Species Code of
2.	Diameter of the tree
3.	Total volume of the tree underbark.
4.	Tree portion 1 volume of the tree underbark.
5.	∠Second tree on the card. ∠ Species Code of
6.	Diameter of the tree.
7.	Total volume of the tree underbark
8.	Tree portion 1 volume of the tree underbark.
9.	∠Third tree on the card. ∠ Species code of
10.	Diameter of the tree.
11.	Total volume of the tree underbark.
12.	Tree portion 1 volume of the tree underbark.
13.	Land class
14.	Legal status
15.	Topography.
16.	Slope
17.	Vegetation
18.	Forest Types

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Item No.	Description
19.	Top height
20.	Size class
21.	Stocking
22.	Plot No.
23.	Block No.
24.	Map sheet No. coded as 1 for 8117 and 2 for 8217.
25.	Photointerpretation data.

The photointerpretation data consists of 4 elements and is packed into one 4 digited number of which first digit is forest cover, second is the density, third is stratum, and fourth is enumeration code. This data is only on the disk and not punched into cards.

ENCLOSURE - VI

LAY OUT OF PLOT SUMMARY FILE

The plot summary file is stored on disk. One record consists of 7 sectors each of which first two are in fixed point mode. They contain descriptive information of plots. Next 5 sectors are in floating point mode and give number of stems, total volume underbark, tree portion 1 volume underbark, utility class 1 volume underbark, utility class 2 volume underbark, utility class 3 volume underbark and utility class 4 volume underbark. Results are given by 7 diameter classes. (This means that the total No. of items are = 7 x 7 = 49 in 5 sectors). After the error calculation plot summary file has also been punched into the cards. Each plot has got a set of 8 corresponding cards giving the same information as recorded on the disk. The card design code for plot summary cards is 8.

Lay out of card type 1 (Plot Description)

Sl.No.	Description	Card Cols.
1.	Job No.	1-3 (Always 198)
2.	Card Design	4-5 (Always 08)
3.	Sub Card Design	6 (Always 1 - Plot description)
4.	Stratum	7
5.	State	8-9
6.	Revenue District	10-11
7.	Forest Division	12-13
8.	Land class	14
9.	Legal status	15
10,	Altitude	16-17

Contents

Sl.No.	Description	Card Cols.
11.	Topography	18
12.	Slope	19
13.	Position on slope	20
14.	Aspect	21
15.	Stoniness	22
16.	Humus	23
17.	Soil colour	24
18.	Soil consistency	25
19.	Soil texture	26
20.	Soil depth	27
21.	Vegetation	28
22.	Origin of stand	29
23.	Forest type	30-31
24.	No. of storeys	32
25.	Top height	33-34
26.	Size class	35
27.	Stocking %	36
28.	Regeneration	37
29.	Bamboo occurrence	38
30.	Bamboo species	39-40
31.	Bamboo quality	41
32.	Bamboo regeneration	42
33.	Biotic influence	43
34.	Past treatment	44
35.	Proposed treatment	45

Sl.No.	Description	Card cols.
36.	Grass incidence	46
37.	Fire incidence	47
38.	Blank	48-49
39.	Forest cover (P.I. data)	50
40.	Forest density (P.I.data)	51
41.	Stratum (P.I. data)	52
42.	Enumeration code	53
43.	Utility class 1 vol.u.b.	54-58 (to be read as F.5.3)
44.	Utility class 2 "	59-63 (" " ")
45.	Utility class 3 "	64-68 (" " ")
46.	Utility class 4 "	69-72 (" " F.4.3)
47.	Plot No.	73
48.	Block No.	74-77
49.	Map sheet	78
50.	Inventory Design	79-80

Lay out of other cards (2-6)

Sub card design numbers (2-6) given in column 6 specifies other card types. Each card type is intended to give information about separate character as given below:

Sub card design No.	Description of the character
1	Number of stems by diameter classes.
2	Total volume underbark by dia. classes.
3	Volume of tree portion 1 by dia. classes
4	Utility class 1 volume u.b. by dia. classes
5	Utility class 2 " " "
6	Utility class 3 " " "
7	Utility class 4 " " "

Contents

The card lay out for all of them is very similar. General plan is given below:

S.No.	Description	Col.No.
1.	Job No.	1-3 (Always 198)
2.	Card Design	4-5 (Always 08)
3.	Sub card design	6
4.	Stratum	7
5.	Result for diameter class-1	8-12
6.	Result for diameter class-2	13-17
7.	Result for diameter class-3	18-22
8.	Result for diameter class-4	23-27
9.	Result for diameter class-5	28-32
10.	Result for diameter class-6	33-37
11.	Result for diameter class-7	38-42
12.	Total volume u.b. for the plot	43-47
13.	Tree portion 1 vol.u.b.	48-52
14.	Utility class 1 "	53-57
15.	" " 2 "	58-62
16.	" " 3 "	63-67
17.	" " 4 "	68-72
18.	Plot No.	73
19.	Block No.	74-77
20.	Map sheet	78
21.	Inventory Design	79-80

The general format to read information from any of these cards is as follows:

FORMAT (I3, I2, 2I1, 13F 5.2, I1, I4, I1, I2)

For each card design value for corresponding character is pu

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