PRACTICAL MANUAL

Forest Inventory and Yield prediction

Course No. FNR 417 Credit Hrs. 2(1+1)

B.Sc. (Hons.) Forestry VIII Semester

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2020

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Jhansi – 284003

Syllabus

Study the demarcation and alignment of plots, strips etc. Field exercise on Horizontal Field demonstration of various sampling techniques- Simple, stratified, multi stage, multiphase, non- random sampling techniques. Visit forest areas for forest enumerations- point sampling- use of wedge prism and Relaskop - Field exercise on the determination of site quality -Visit to local forest divisions and study the methods of preparation and use of yield tables. Method demonstration on the use of aerial photographs in forest inventory

Name of Student ....

Roll No. ....

Batch ....

Session ....

Semester ....

Course Name : ....

Course No. : ....

Credit ....

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CERTIFICATE

This is to certify that Shri./Km. ....ID No................................... has completed the practical of course...course No. .... as per the syllabus of B.Sc. (Hons.) Agriculture/ Horticulture/ Forestry .... semester in the year.....................in the respective lab/field of College.

Index

Practical No. 1

Objective: Study of form / taper of trees

Objective: ....
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Material Required: ………………………………………………………………………………………
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Procedure: …………………………………………………………………………………………………
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Form Factor: ……………………………………………………………………………………………..
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Form factor (F) Formula: ………………………………………………………………………………....
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Classification of form factor

1. **Artificial form factor (Breast height form factor):** ………………………………………………...

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2. **Absolute form factor:** ………………………………………………………………………………

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3. **Normal (tree) form factor:** ……………………………………………………………………

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Form Quotient (Developed by A. Schiffel): ……………………………………………………

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Formula = $\frac{\text{mid diameter}}{\text{DBH}}$ **or** $\frac{\text{mid girth}}{\text{GBH}}$

Classification of form quotient

1. **Normal form quotient:** ……………………………………………………………………

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2. **Absolute form quotient:** ……………………………………………………………………

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Diagram

Observation and Calculation:

Sl. No.	Tree Name	DBH (cm)	Mid-dia. (cm)	Dia. at ½ the height above the DBH (cm)	Normal Form Quotient	Absolute Form Quotient	Remarks
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Practical - 2

Objective: - Study about volume estimation of standing trees

Material required: ……………………………………………………………………………………………

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Methods of Volume of standing trees

I. Ocular
II. Partly ocular and partly measurement
III. By direct and indirect measurement
IV. By volume tables

For getting relatively more accuracy, the last two methods *i.e.*-direct measurement and volume tables methods are used.

Direct measurement method

1. **First method:** ……………………………………………………………………………........................

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By General formula-

A. If the tree is in conical shape

$$V = S \times H/3$$

$$= (\pi D^2/4) \times H/3$$

$$= \pi D^2 H/12$$

where, V= Volume of tree (m^3); S= Basal Area of tree (*i.e.* $S = \pi D^2/4$ & unit is m^2); H= Commercial bole height or height of tree (m)

B. If the tree is in cylindrical shape

$$V = S \times H$$

$$= (\pi D^2/4) \times H$$

where, V= Volume of tree (m^3); S= Basal Area of tree (*i.e.* S = $\pi D^2/4$ & unit is m^2) and H= Commercial bole height or height of tree (m)

2. **Second method:** …………………………………………………………………………………………

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By Quarter Girth formula

$$V = (G/4)^2 \times H$$

where, G= Girth at mid-point (G = πd & unit is m; d is mid-point diameter); H= Commercial bole height or height of tree (m)

3. **Third method:** …………………………………………………………………………………………..

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By using form quotient to get volume -

$$V = S \times F \times H$$

$$= (\pi D^2/4) \times F \times H$$

where, V= Volume of tree (m^3); S = Basal Area of tree (*i.e.* S = $\pi D^2/4$ & unit is m^2); F = Normal Form Quotient (=Mid-diameter/DBH); H= Commercial bole height or height of tree (m)

Observation and Calculation:

Table-1 (Volume calculation by General formula)

Sl. No.	Species Name	DBH in cm (D)	Commercial Bole height/ height of tree in meter (H)	Basal Area in m^2 (S= $\pi D^2/4$)	Volume (m^3)	
					Conical	Cylindrical
					V= S x H/3 = $\pi D^2 H/12$	V= S x H = $\pi D^2 H/4$
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Table-2 (Volume calculation by Quarter Girth formula)

Sl No	Species Name	Mid-point diameter (d) in cm	Commercial Bole height/ height of tree(H) in m	Mid-point girth in m (G = πd)	Volume (m3) V= (G/4)2 x H
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Table-3 (Volume calculation by using form to calculate volume)

Sl No	Species Name	Normal Form Quotient (F) Mid-point diameter/ DBH	Commercial Bole height/ height of tree (H) in m	Mid-point girth in m (G = πd)	Volume (m3) V= S x F x H = πD2 FH / 4
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Practical - 3

Title: Study about volume estimation of felled trees or logs

Objective: ……………………………………………………………………………………………………
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Materials required: ....

Procedure: ..………………………………..………………………………………………………………

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Formula:

Diameter Under Bark (DUB) = ………………….. then,

Convert the DUB into GUB by using formula
Girth Under Bark (GUB) = ………………..

A) Volume calculation of logs of cylindrical form (Over bark)

1. General formula (Measure the diameter at any point of log)
V= S x L
Where, S= Basal Area; L= Length of log

2. Quarter Girth formula (Measure the diameter at middle of log) V= $(G/4)^2$ x L
Where, G= Girth at mid-point of log; L= Length of log

B) Volume calculation of logs of taper form (Over bark)

1. Smalian"s formula, (Measure the diameter at thick end and thin end of log) V = $(S_1 + S_2)/2$ x L

Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section and L = Length of log

2. Huber"s formula (Measure the diameter at middle of log) V = Sm x L
Where, Sm = Basal Area at middle of log and L = Length of log

3. Newton"s formula (Measure the diameter at thick end, middle and thin end of log)
$V = (S_1 + 4\ Sm + S_2)/6 \times L$
Where, S_1 = Basal Area of thick end cross section; S_2 = Basal Area of thin end cross section; Sm = Basal Area at mid-point and L = Length of log

4. Quarter Girth formula (Measure the diameter at middle of log)
$V = (G/4)^2 \times L$
Where, G= Girth a mid-point of log and L= Length of log

Observation and Calculation:

Observation table

Sl No	Species Name	Length of log (L) in m	Dia (OB) at any point (d) in cm (Only for cylindrical form of logs)	Mid-Dia (OB) (D) in cm	Dia (OB) at thick end (D1) in cm	Dia (OB) at thin end (D2) in cm

Calculation Table- (Volume of log(s) over bark by different formulae)

Sl No	Vol. by General Formula (m3) (Only for cylindrical form of logs) [V= S x L]	Vol. by Quarter girth formula (m3) [V= (G/4)2 x L]	Vol. by Smalian's formula(m3) [V=(S1+S2)/2 x L]	Vol. by Huber's formula (m3) [V = Sm x L]	Vol. by Newton's formula(m3) [V=(S1+4Sm+ S2)/6 x L]

Practical - 4

Title: Study of demarcation and alignment of sample plots in forestry

Objective: ……………..……………………………………………………………………………………

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Material required: ……………………………………………………………………………………

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Procedure: ………………………………………………………………………………………………

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Size of the fixed area sampling unit:

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Shape of the fixed area sampling unit:

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Plots: ……………………………………………………………………………………………………

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Strips:

Topographical units:

Cluster:

Sampling intensity:

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<u>Prepare the inventory of vegetation of different satarta (Trees, Shrubs, and herbs)</u>

S N	Species	Dia	Height
	Trees		
	Shrubs		
	Herbs		

Practical - 5

Title: Study of simple and stratified sampling techniques

Objective: ....

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Material Required: ....

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Procedure: ....

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Simple random sampling: ....

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Stratified random sampling: ....

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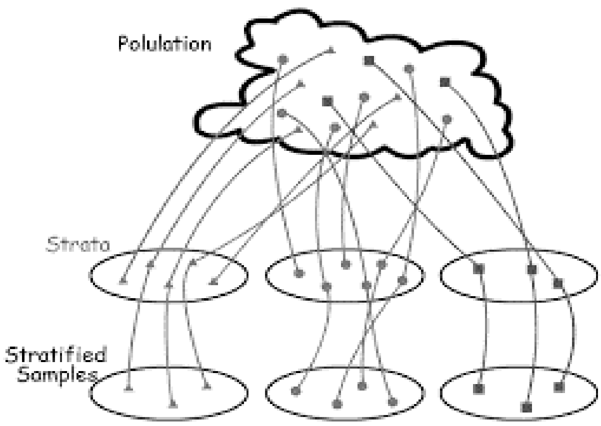

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Exercise to do: Do the simple and stratified sampling in the forest area. Preapre the inventory of a small area.

Practical - 6

Title:Study of multistage and multiphase random sampling techniques

Objective: ....

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Material Required: ....

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Procedure: ....

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Multistage random sampling: ....

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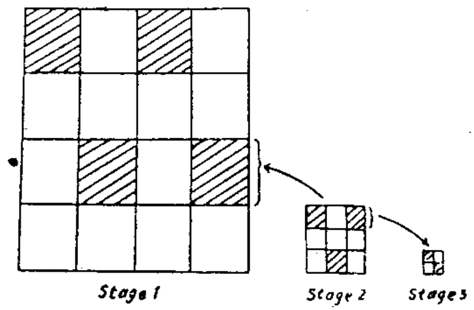

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Multiphase random sampling: ………………………………………………………………………………..
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Exercise to do

Do the Multistage and multiphase sampling in the forest area. Preapre the inventory of a small area.

Practical - 7

Title:Study of non-random sampling techniques

Objective: ....

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Material Required: ....

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Procedure: ....

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Selective non random sampling: ....

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Systematic Non random sampling: ....

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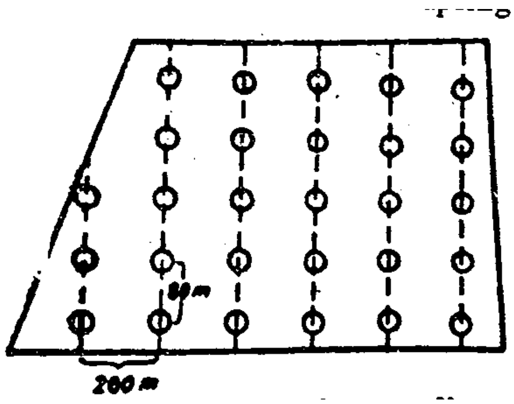
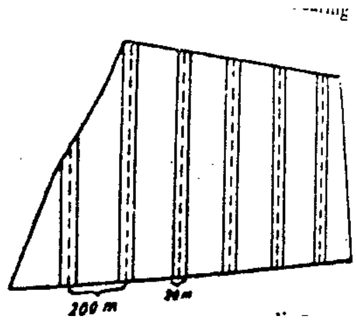


Systematic sampling



Strip sampling

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Sequential sampling: ………………………………………………………………………………………
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Exercise to do

Do the non random sampling in the forest area. Preapre the inventory of a small area

Objective: To study Forest enumeration by point sampling with help of wedge prism & Relascope

Objective: ....

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Material Required: ....

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Procedure: ....

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Horizontal sampling: ....

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Point sampling: ....

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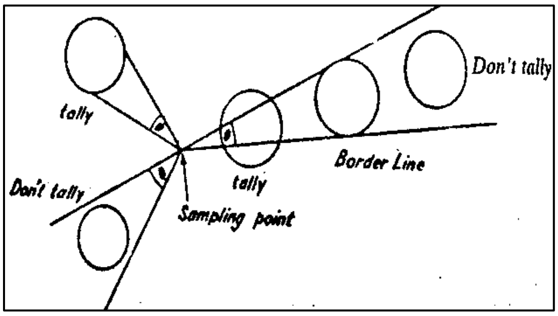

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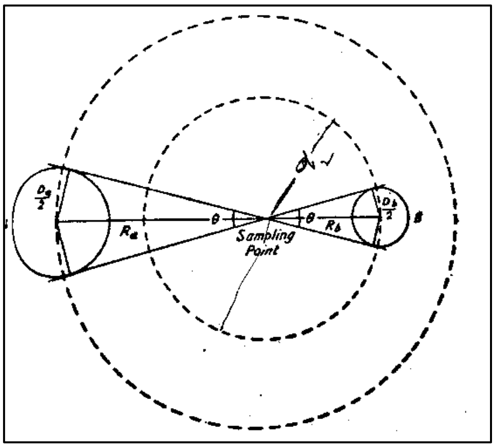
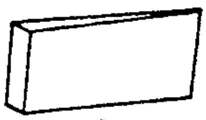
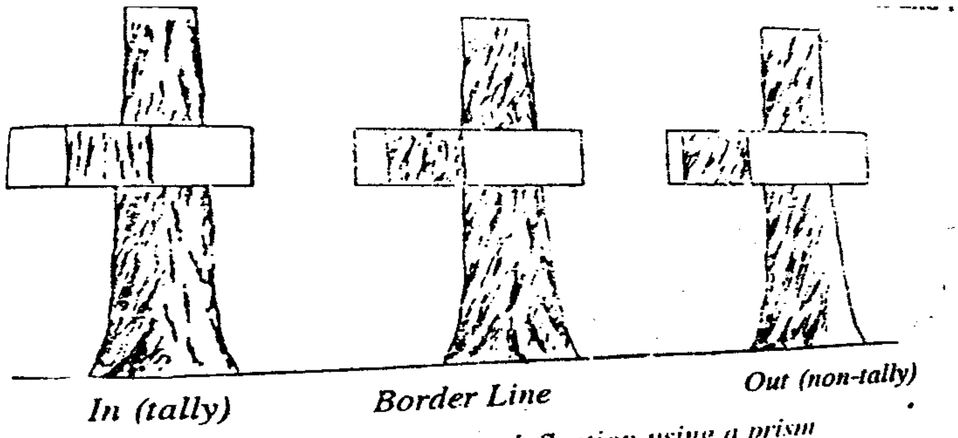
Point sampling:



Point sampling through wedge prism:

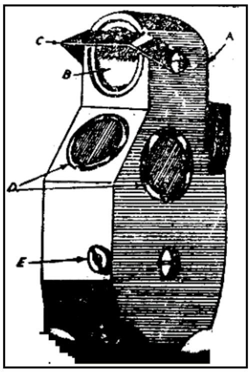


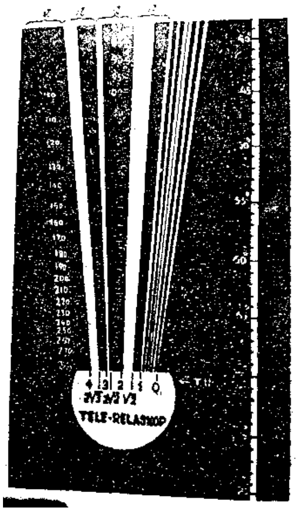
Prism

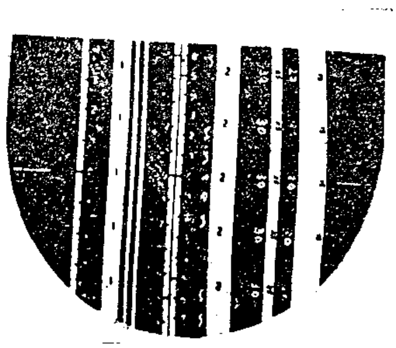


Representation of image deflection using a prism

Point sampling through Spiegel Relascope:

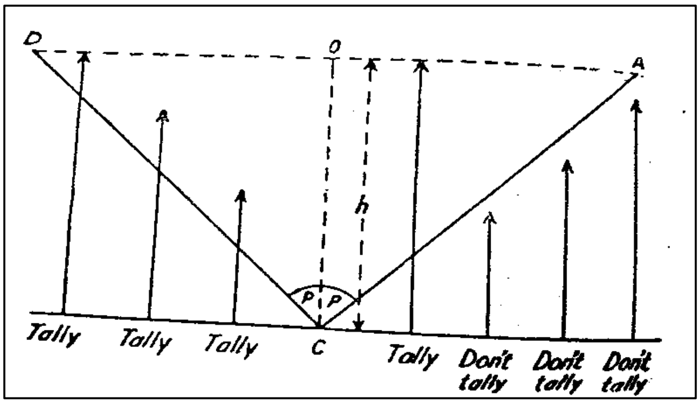






Sacles as seen inside drum

Vertical point sampling: ……………………………………………………………………………



Exercise to do

Do the point sampling in the forest area and preapre the inventory.

Title: Visit of local forests for determination of site quality

Objective: ....

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Material Required: ....

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Procedure: ....

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Site factors: ....

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Vegetative factors: ....

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Plant Indicators: ………………………………………………………………………………………………...

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Tree characterstics: ……………………………………………………………………………………………

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Exercise to do

Vsist the local forest area and preapre the site quality maps/ groups

Practical - 10

Title: Study of yield class system of classifying growth potential of a forest

Objective: ………

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Material Required: ……………………………………………………………………………………………

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Procedure: ……………………………………………………………………………………………………

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Strip height method based on Baur's method: ……………………………………………………………………………

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British Forestry Commission Mthod (BFC): ………………………………………………………………………………

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FRI Method: ……………………………………………

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Exercise to do

Vsist the local forest area and preapre the site quality maps/ groups

Practical - 11

Title: Study of volume measurement methods in sample plot

Objective: ....

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Material Required: ....

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Procedure: ....

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Arithmetic mean sample tree method: ....

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One-inch diameter class method or Hossfeld's method: ....

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Huber's method: ……………………………………………………………………………………...

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Urich's method: ……………………………………………………………………………………….

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Hartig's method: ……………………………………………………………………………………...

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Blocks method: ....

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Number of diameters per ha	Number of groups and number of diameters per group
2-298	65 + 65 + Rest
300-498	125 + 125 + Rest
500-624	125 + 125 + 125 + Rest
626-874	125 + 125 + 125 + 125 + Rest
876-1125	125 + 125 + 125 + 125 + 250 + Rest
1126-1374	125 + 125 + 125 + 125 + 250 + 250 + 250 + Rest
1376-1624	125 + 125 + 125 + 125 + 250 + 250 + 250 + 250 + Rest
1626-1876	125 + 125 + 125 + 125 + 250 + 250 + 250 + 250 + Rest
Over 1876	125 + 125 + 125 + 125 + 250 + 250 + 250 + 250 + 250 + Rest

Steps to be followed:

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Exercise to do

Vsist the local forest area and preapre the basal area/ volume cahrt of sample plots

Table: Measurement of sample trees

Sample tree No.	Species	Age	Total height	Length of shoot of last year	Diameter at height L			Basal area	Volume measurements				Vol. od cylinder	Form factor				Bark thickness	Bark %	Remarks
					D1	D2	Av.		Timber		Small wood			timber		Small wood				
									stem	branch	stem	Branch		stem	branch	stem	branch			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Table: Volume calculation (Two diameter and Table calculation)

By diameter class			By groups		Calculated mean tree								
Diameter	No. of dia	Basal Area	No. of Dia	Basal area	Basal area	Dia	Height	Form factor			Volume		
								Stem timber	Small wood		Stem timber	Small wood	
									stem	branch		stem	branch
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Practical - 12

Title: Study methods of determine past growth of stand

Objective: ………

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Material Required: ……………………………………………………………………………………………..

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Procedure: Permanent sample plot is laid to record periodic data for determination of past growth. The two common methods used for this purpose includes

1. The method of control
2. Continuous forest Inventory method

The method of control: ……………………………………………………………………………………...

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Example

Diameter class (cm)	**Initial inventory in 1970 (number)**	**Second inventory in 1980 (Number)**	**Tree rising (Number)**	**Double rising (Number)**	**Double effective (Number)**	**DR/DE**	**Periodic diameter increment (cm)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
			0				
100	1	2		1	3	0.33	3.3
			1				
90	3	5		4	8	0.50	5.0
			3				
80	8	8		6	16	0.38	3.8
			3				
70	9	11		8	20	0.40	4.0
			5				
60	15	25		20	40	0.50	5.0
			15				
50	20	30		40	50	0.80	8.0
			25				
	56	81		79	137 ∑DR/ ∑DE= 0.58 Average		

The figure column 4 in the table above line shows tree rising out and blow line shows tree rising into the class.

Continuous Forest Inventory Method (CFI): ……………………………………………………………….

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Exercise to do

Do calculation for determination of past growth of stand with suitableexample.

Practical - 13

Title: Study the methods of yield table preparations

Objective: ....…

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Material Required: ………………………………………………………………………………………..

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Procedure: ………………………………………………………………………………………………….

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Content of Yield table

Contents of yield table can vary depending upon the various factors of field operation and data collection. The important contents are

Main crop	Thinning	Final yield	Accumulated yield of thinning
(i) Average diameter, (ii) Average height (iii) Total basal area (iv) Number of trees (v) Stem timber form factor (vi) Total (stem & branch) small wood form factor (vii) Standing volume stem timber (viii) Standing volume total small wood (ix) Total standing volume i.e. stem and small wood	(i) Volume of stem timber (ii) Volume of total small wood (iii) Total volume	(i) Volume stem timber (ii) Volume total stem wood (iii) Total volume	(i) Volume of stem timber (ii) Volume total small wood (iii) Total volume
Total yield	**Mean annual increment**	**Current annual increment**	
(i) Volume of stem timber (ii) Volume total small wood (iii) Total volume	(i) Volume small timber (ii) Total volume	(i) Volume stem timber (ii) Total volume	

This content of yield table grouped in two classes as primary data and secondary data.

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Kinds of yield table: ……………………………………………………………………………………………

(a) On the basis of number of grades of thinning used:

1. ………………………………………………………………
2. ………………………………………………………………

(b) On the basis of volume or value given:

1. ....
2. ……………………………………………………………..

Preparation of Yield table: ....

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Exercise to do

Do primary excerises of volume table analysis

Table: Summary of sample tree measurements

Species---------

Div	Sample plot No.	Sample tree No.	Crown class	Age	Dia	Tot. Ht.	Length of shoot of last year	From factor				Solid volume				Bark thickness	Bark %	Length of stem	Crown height	Crown width	Ratio of CH/CW	Form quotient		% of sapwood in stem timber
								timber		Small wood		timber		Small wood								Over bark	Under bark	
								stem	branch	stem	branch	stem	branch	stem	branch									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Table: Record of Periodic volume measurement per acre or ha.

Year of Measurement	Treeage/ age of crop	sps	Main crop													
			No. of trees /acre	Height		Form factor			Diameter			Basal area per acre after thinning	Volume per acre			Total
				Av. Ht of tallest trees	Av. of crops	Stem timber	Small wood		Min	Max.	Av		Stem timber	Small wood		
							stem	total						stem	total	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Table: Intermediate yield from thinning

No. of trees	Av. height	Dia			Basal area	Vol. per acre			Total	Total crop		Increment of final crop			
		Min	Max	Av.		Stem timber	Small wood			Basal area	Timber	Periodic		Periodic mean	
							Stem	total				Basal area	Stem timber	Basal area	Stem timber
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Practical No. 14

Title: Study of Wood Density

Objective: ………
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Material required: ………………………………………………………………………………………………
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Procedure: ………………………………………………………………………………………………………
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Density (ρ): ………………………………………………………………………………………………
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Formula: $\rho = \frac{m}{V}$ *m*; mass, *V*; Volume

Volume measurement –

Geometrical method ……………………………………………………………………………………………
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Water displacement method………………………………………………………………………………………
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e.g. Volume of specimen = New water level – Original water level
= 1220 – 1000 = 220 ml

Mass of specimen = 520 gms
Density = 520/220 = 2.36 gm/ml
Since, 1 ml = 1 cm3;
Density of a specimen can be expressed as 2.36 gm/cc

Observation and Calculation

Sl. No.	Mass	Volume by geometry	Volume by water displacement	Density*	Density#
1)					
2)					
3)					
4)					
5)					
6)					
7)					
8)					
9)					
10)					

*density calculated using volume estimated by geometry method
#density calculated using volume by water displacement

Practical 15

Title: Prediction of biomass and volume in forest stands

Objetcive: ………………………………………………………………………………………………...

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Material required: ……………………………………………………………………………………

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Biomass estimate is to develop an allometric equation that will allow us to estimate the mass of a tree from a few simple measurements of it and then to apply this equation to the trees in a forest. The term allometry is defined as "the measure and study of relative growth of a part in relation to an entire organism or to a standard". It is based upon a principle first describe by Galileo Galilee in the 1630's

Procedure: ……………………………………………………………………………………………

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Biomass measurement: ……………………………………………………………………………………

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Tree Diameter: ……………………………………………………………………………………………

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Tree Height: ………………………………………………………………………………………………

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Analysis of dry oven mass and wood density: ………………………………………………………

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Laboratory analysis: ………………………………………………………………………………………

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Total dry weight (TDW) for each organ of the sample tree: …………………………………………………………..

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$$TDW = TFW \frac{SDW}{SFW}$$

Where: *TDW* is total dry weight; *TFW* is total fresh weight; *SDW* is absolute dry sample weight and *SFW* is fresh sample weight.

Wood density: …..…………………………………………………………………………………………

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Volume measurement: ……………………………………………………………………………………

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Regression analysis: ……………………………………………………………………………………..

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Data sheets to record tree harvesting data

Species Name		Place		Age	
Tree No.		Spacing			
Tree height (m)		GBH (cm)			
Log number	Log length (m)	Log girth			
		Lower end	Middle end	Top end	Fresh Weight
1					
2					
3					
4					
5					
6					
7					
8					
Branch fresh weight (kg)					
Leaves fresh weight (kg)					
Sample	Fresh weight	Dry weight			
Bole					
Leaves					
Branch					

Practical: The raw data has been taken by harvesting poplar trees planted at 5x4 m spacing. Students should use the procedure given in the exercise and develop the component-wise biomass equations.

Poplar biomass (kg/tree)									
Tree No.	**DBH (cm)**	**Height (m)**	**Component wise biomass (kg/tree)**						
			Stem	**Branch**	**Leaves**	**ABG**	**Root**	**Total biomass**
1	**27.2**	**13.2**	247.8	50.2	17.6	315.6	56.7	**372.3**
2	**28.3**	**13.5**	262.1	55.0	19.3	336.4	58.2	**394.6**
3	**28.0**	**13.5**	255.9	54.4	18.4	328.7	62.0	**390.8**
4	**22.6**	**14.2**	172.0	38.0	13.5	223.5	38.6	**262.0**
5	**27.2**	**19.2**	267.0	44.4	17.5	328.9	50.5	**379.4**

Practical No. 16

Objective: To apply aerial photographs in forest inventory

Objective: ……...

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Material Reqquired: ………………………………………………………………………………………….

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Procedure: …………………………………………………………………………………………………….

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Classification of Aerial photo graphs

On the basis of film used

1. ……
2. ……
3. ……
4. ……

On the basis of device used

1. ……
2. ……
3. ……

On the basis of scale of photograph

1. ……
2. ……
3. ……
4. ……

On the basis of position of optical axis of camera

1. ……
2. ……
3. ………..
4. ……

India like country where large climatic variations season play important role in photography of vegetation. Broad season for aerial photography is indicated below

Broad vegeational group	Optimum season for aerial photography
(i) Coniferous forests in Himalayas	
(ii) Mixed deciduous forest without teak and sal	
(iii)Sal forests – northern India - Central & Eastern India	
(iv)Teak Forests- northern India - Central & Southern India	
(v) Tropical evergreen and moist deciduous forests	

Aerial photographs are further studied by Photo interpretation which is a technical parlance of examining images and judging their significance. This exercise involves two part (i) the interpreter and (ii) the Photograph.

Features for Identification of Object

1. ………
2. ………
3. ………
4. ………
5. ………
6. ………
7. ………
8. ………

Stereoscopy: ………………………………………………………………………………………………

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Photogrammetry: …………………………………………………………………………………………

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Measurements of stand characteristics through spectroscopy and photgeometry from arieal photographs

- Stand Crown Diameter ……………………………………………………………………………………
- Stand Height ………………………………………………………………………………………………
- Crown Density ……………………………………………………………………………………………..
- Crown Count ………………………………………………………………………………………………
- Stand Volume …………………………………………………………………………………………...

Measurements of stand characteristics through spectroscopy and photgeometry from arieal photographs

- Stand Crown Diameter ……………………………………………………………………………………
- Stand Height ……………………………………………………………………………………………...
- Crown Density …………………………………………………………………………………………
- Crown Count ……………………………………………………………………………………………...
- Stand Volume …………………………………………………………………………………………...

Exercise to do

Do analysis of aerial photo graphs with peirmay application of photo interpretation for preparation of forest inventory

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STUDY OF FORM OF TREES

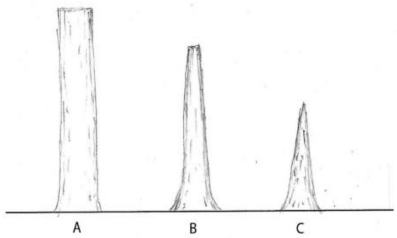
The form of trees varies among trees according to their presence *i.e.* open or dense forest conditions. Similarly, it also varies with age of trees from juvenile to mature stage.
Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Dendrometer

Procedure: The form of trees can be studied by comparison of standard form ratios which is of two types *viz.* form factor and form ratio.

Form Factor: It refers to the ratio of the volume of a tree or its part to the volume of a cylinder having the same length and cross section as the tree. (Or it is ratio between the volume of a tree to the product to the basal area and height)

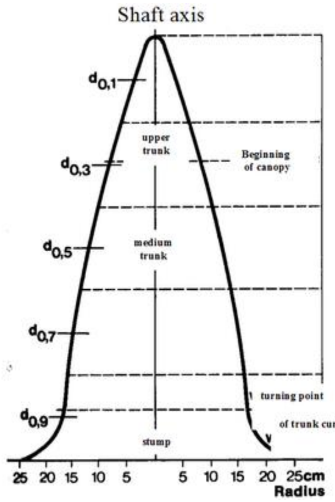
Form factor (F) $= \frac{V}{Sh}$
Where, V= Volume of tree; S = Basal Area and h = Height of tree

Classification of form factor



1. **Artificial form factor (Breast height form factor):** Basal area is measured at breast height (BH) and the volume refers to the whole tree both above and below the point of measurement of BH.
2. **Absolute form factor:** Basal area is measured at any convenient height but volume and height of the tree are above the point of the measurement (Ratio between the volume of the tree above the point of diameter or basal area measurement with the cylinder which has the same basal area and whose height is equal to the height of the tree above that point).
3. **Normal (tree) form factor:** Basal area is measured at a constant proportion of the total height of the tree. *E.g.,* 1/10th, 1/20th, etc. (average of these measurement will give the basal area) of the total height and the volume and height are calculated and measured respectively for the whole tree above ground level.

Form Quotient: (Developed by A. Schiffel)



F.Q $= \frac{Mid-diameter}{DBH}$ **or** $= \frac{Mid-girth}{GBH}$

Form Quotient is the ratio between the mid diameter and DBH or ratio between the mid- girth and GBH.

Classification of form quotient

1. **Normal form quotient:** Ratio of mid- diameter or mid –girth of a tree to its diameter or girth at breast height, respectively.
2. **Absolute form quotient:** Ratio of diameter or girth of a stem at one half of its height above the breast height to the diameter or girth at breast height, respectively.
   As per availability of instrument, the form quotients of trees are determined. For this, measure the mid-diameter and diameter of a stem at one half of its height above the breast height with the help of dendrometer. Later, measure DBH of tree using calliper.

VOLUME ESTIMATION OF STANDING TREES

Material required: 1.Ravi altimeter, 2. Calliper, 3.Tape, 4. Pentaprism or Dendrometer (as per availibility)
Procedure: Volume of standing trees can be measured by different methods such as- Ocular, Partly ocular and partly measurement, By direct and indirect measurement, By volume tables. For getting relatively more accuracy, the last two methods *i.e.*-direct measurement and volume tables methods are used.

Direct measurement method

First method- In this method, generally, the diameter of tree(s) decreasing from ground level to top (called as tapering). So the shape of the tree bole is in the form of a cone. The volume of the tree up to commercial bole height is calculated. For example, the volume of tree can be calculated by assuming tree shape as conical. In the direct measurement method, commercial bole height is measured by Ravi altimeter and DBH (diameter at breast height) by caliper and used in the volume estimation by assuming tree in the conical form. Again, if the stem or trunk of a tree is in cylindrical shape up to commercial or merchantable bole height, then DBH and commercial bole height to be measured as per above mentioned procedure. In case of estimation of volume of entire tree, the same procedure is followed by measuring total height and DBH. In all the above cases, appropriate formula can be used for determination of volume.

Second method: In this method, the commercial bole height (or entire height) of standing tree is measured by using Ravi altimeter and the upper stem diameter at the mid- point of commercial bole height is measured by using Pentaprism or Dendrometer. Then, volume of tree is measured using following formula.

Third method: In this method, normal form quotient is used while calculation of volume of tree, where normal form quotient (F) is generally determined from the DBH and mid- point diameter (i.e., Mid-diameter/ DBH). The following formula is used to calculate volume of tree (either up to commercial bole height or entire tree height).

DEMARCATION AND ALIGNMENT OF SAMPLE PLOTS

Objective: Forest inventory or forest survey or forest cruising are conducted by certain sampling design and require laying out of sample plots for collection of varied information of forest as per objective. Sample plot are primary unit to collect basic information with utmost clarity.

Material required:- 1.Ravi altimeter, 2. Calliper, 3.Tape, 4. Pentaprism or Dendrometer (as per availibility)

Procedure: Sample is a representation of a population. Sampling unit are of two kindsviz, those having a fixed area or those having only points.

Size of the fixed area sampling unit: The general statistical consideration, small sampling units are more efficient than larger ones as larger number of independent sampling unit will provide better precision. So sampling intensity and sample numbers are to be harmonized i.e. high sampling intensity distributed in large number of sampling units for better result. Further in forest sampling unit size also depend upon variability and density of the stand. Less dense stands exhibit more heterogeneity and requires carful enumeration of sample plots. The time and cost also important factors in deciding number of sampling unit i.e. more the number more will be time and cost irrespective of area. A general rule is a sampling unit should have at least 20 measurable trees.

Shape of the fixed area sampling unit: The usual shape of sampling units in practice are plots, strips, topographical units and clusters.

Plots: It is applied to sampling units of small area but of the diverse shapes as square, rectangular, circular or polygonal but square and rectangular plots are commonly used in forest surveys specially in regular spaced plantations with sample plot size 0.1 ha – 1.0 ha. Circular are also used as being easy to lay and has the minimum perimeter for a given area compared to any other geometric shape which leads to minimum number of border line trees. In India circular plots 0.05 ha (12.62 m radius) and 0.1 ha (17.84 m radius) has been used in most of past forest surveys.

Strips: These are 20 to 40 meters wide strips laid across the forest form one end to the other at a particular bearing at regular intervals and inventory of these strips is made to serve as a sample. For this decide a base line at one end of the forest and start cutting a line the forest at a fixed bearing from afixed point on the base line. Strips are 100m to 200 m apart and each strip is the sampling unit but often divided into 100 m lengths to serve as recording unit. Sampling intensity I calculated as

$I = (W/D) \times 100$ Where, I is intensity of sampling, W is the width of strips in meter and D is distance in meter between the central lines of the two adjacent strips

Topographical units: Sampling unit whose boundaries are predominant topographical or natural features such as nalas, streams, ridges, artificial features etc. these can be shown on the maps and can be fixed with exactitude on the ground.These are mostly used in the hill forests with convenient varying sizes of 12 to 24 ha area. These areas can be further stratified and made to homogenous blocks for observations. In hills vegetation and productivity zones are function of altitude, aspect, slope and geology which need to be addressed as as possible selecting the sampling units. In this sampling units are large and number is less so standard error is higher than plots & strips.

Cluster: it is group of small sapling units. Cluster is statistical unit whereas the smaller ones only record units. The information collated in each record unit and then merged to form sampling unit (cluster).

Sampling intensity: It is percentage of the area of the population to be included in the sample. This depend upon the object of inventory, the type of forest inventoried, kind of sampling being used, time and money a viable, degree of accuracy aimed and precision required. Normally recommended sampling intensity for various type of forests are

Tropical wet evergreen- 10%; Tropical moist deciduous forest- 2.5 %; and subtropical pine forests- 5%. Further with respect to terrain also sampling recommended as –

Plain areas- Strip sampling-5-10%; Line plot survey (0.05 ha circular equidistant plots on parallel lines)- 2- 5%.
Hill areas- topographical units- 20- 25 % when area is more than 2000ha.

Sapling intensity and number of independent sampling units both are to harmonies as per survey area. High sampling intensity with less number of sample plot will not be so accurate estimates as same intensity with large number of sampling units.

Sample plot: It is plot chosen a representative of alarger area. In forestry they are used to study the growth of a stands and to study the effects of some treatments. They can temporary orpermanent as per objective and so the measurements are carried out either once or at repeated intervals over period of time respectively. Temporary sample plots are used in enumeration surveys while permanent plots for growth and yield in different site qualities with certain treatments as well e.g. thinning effect, fertilizers application.

Plots are generally laid in even aged pure and fully stocked/ uniform stocked crops and well distributed over the whole range of site qualities. Number of plots depends upon the species, number of age classes, quality classes, and variation in treatments with minimum 2 plots at decadal interval. About 600 plots for each thinning regime for one species are considered enough for preparation of yield tables. The shape of plots may be circular, rectangular or square. Circular plots are easy to lay but in standing forest rectangular plots are commonly laid with size 0.1 to 02. Ha. The layout of the plot includes laying out a surround, demarcation of plot boundary, marking crossmarks, and numbering of trees in the plot and preparing a plot chart.

SIMPLE AND STRATIFIED SAMPLING TECHNIQUES

Objective: -Simple and stratified random sampling are two important sampling techniques which are commonly followed in all types of forestry inventory preparation. They are used in different way by applying principle of homogeneity and making population as far as uniform for selection.

Material required:- 1.Ravi altimeter, 2. Calliper, 3.Tape, 4. Pentaprism or Dendrometer (as per availibility)

Procedure: In random sampling,sample are selected in such a manner that all possible units of the same size have equal chance of beingchosen. There are different variations of random sampling viz, simple, stratified, multistage, multiphase, samplingwith varying probability, list sampling etc.Insimple and stratified random sampling, sampling units are drawn from the population at one time or one stage and therefore also called as single stage sampling

Simple random sampling: Unrestricted or simple random sampling has to select samples in strictly random process from whole population or diving the area in homogenous block. e.g. 1000 ha area to be sampled by 0.1 ha sample plots. The area will be divided into 10000 sampling units and if 5 % is area to be sampled so we will take 500 sample units by random selection from whole area.

Stratified random sampling: In this sampling the whole area is first divided into sub populations of different strata and then sampling units are selected from each of the strata in proportion to their size. This sampling method is quite common in forest crops as there is more heterogeneity in population. It requires to make homogenous strata which called stratification and then samples are selected from each such start. In forest inventory this done by forming strata by species, site qualities, crop density etc., e.g.1000 ha area to be sampled by 0.1 ha sample plots. The area is divided into 4 groups/ strata on the basis of site quality as I- 300 ha, II- 350 ha, III- 200 ha, and IV- 150 ha. If 5 % is area to be sampled so we will take sample units proportion to each site quality area (stratum) by random selection as 150,175,100 and 75 respectively for each I, II II and IV stratum.

MULTISTAGE AND MULTIPHASE RANDOM SAMPLING TECHNIQUES

Objective: Multistage and multiphase random sampling are two important sampling techniques which are other two commonly followed in all types of forestry inventory preparation. They are used in different way by applying principle of homogeneity and making population as far as uniform for selection.

Material required: 1.Ravi altimeter, 2. Calliper, 3.Tape, 4. Pentaprism or Dendrometer (as per availibility)

Procedure: In random sampling,sample are selected in such a manner that all possible units of the same size have equal chance of beingchosen. There are different variations of random sampling viz, simple, stratified, multistage, multiphase, sampling with varying probability, list sampling etc.

Multistage random sampling Unlike simple and stratified random sampling where sampling is taken in one time or one stagehere some samples are taken in one stage and then divide the selected sample in more sampling units at next stage or so on. As the samples are taken in successive stages and not in single time it called multistage sampling. The principle of random sampling is maintained at each stage of sampling. E.g. A forest area of 100ha may be divided into 200 sampling units of 0.5 ha. If 5 % sampling is to be carried out 10 sample plots are needed. Further in next stage each 0.5 ha selected sample plots are divided into 0.1 ha subplots making 5 subplots in each main sample plots. Now in second stage among these five any one or two will be randomly selected. It can be further subdivided to new sub plots or to select individual trees from subplots for measurements in forest inventory. E.g. In forest divison a compartment is a unit which further divided into equal size subplots in second satge while in third satge individual trees are selected for measurements. Two sage sampling is common in forestry surveys.

Multiphase random sampling In this sampling method same sampling units are used at the different phases of the sampling to collect different information or same information by different. I forest inventories generally it is carried out in two phases therefore also called two phase or double sampling. E.g. Estimation of bamboo culms in forest to be carried out, then in first pahse the number of clumps per hectare is determined by the large systematic surveys and second pahse., number of clms per clump is determined from small enumeration survey of small area from the first phase. Similarly, in forest inventories combined use of aerial photographs and filed plots can be called as double phase sampling. Here we can estimate volume or stocking of forest of large area by ground truthing of small sub plots of aerial photographs by drawing a regression which also save money from manual map based estimation.

NON-RANDOM SAMPLING TECHNIQUES

Objective: -Non random sampling is a method of sampling in which samples are selected according to the subjective judgement of the observer on the basis of certain rules and guidelines indicating what sample should be chosen.There are different types of non-random sampling.

Material required:- 1.Ravi altimeter, 2. Calliper, 3.Tape, 4. Pentaprism or Dendrometer (as per availibility)

Procedure: In non-random sampling,sample are selected by subjective judgement and field experience of the person. There are different variations of no random sampling viz, Selective sampling, Systematic sampling and sequential sampling etc.

Selective non random sampling: It consistsof choosing samples according to the subjective judgement of the observer. Selective sampling may give good approximations of population parameters if it is properly used by a person with intensive knowledge of population. 4 PEA sampling described by Gyde Land and La Bou (picking plots by personal prejudice and/ or ease of access) I one of the forms of selective sampling. This sampling commonly used quick rough estimates.

Systematic Non random sampling: In this method of sampling, sampling units are selected according to predetermined pattern without recourse to random selection. Most common method pattern of regular spacing of units in a transect or area.eg. sampling units located at 50 mts apart in rows which may 200 mts apart. The selection of first unit may be either random or according to a fixed arbitrary rule. So the sampling two variants a. systematic sampling with random start b. systematic sampling with fixed start It usually applied in forestry as have more advantage than random sampling specially in tropical forests where environmental condition hampers the work. It is simple, easy to work and more uniform distribution of samples to give desired results.

Sequential sampling: This type of sampling characteristicsis that the number of observation in the sample is not determined in advance but sampling unis are taken successively from a population. Each sample includes all the sampling units of the former sample sampling is stopped when desired precision is reached. This type of sampling is adopted to test the hypothesis.

FOREST ENUMERATION BY POINT SAMPLING WITH HELP OF WEDGE PRISM & RELASCOPE

Objective: In random method sampling point sampling is one of the method. Bitterlichhas proved that counting from a random point the number of trees whose breast height cross section exceeds a certain critical angle when multiplied by a constant factor gives an unbiased estimate of basal area per ha. This techniquecalled by different names viz., Angle count cruising, Pointless cruising, Point sampling, variable plot cruising, PPS (Probability proportional to size), Polyareal plot sampling.

Material required:- 1.Wedge prism, 2. Calliper, 3.Tape, 4. Relascope (as per availibility)

Procedure: In random method sampling point sampling is one of the method which also extensively used in forest inventories. Point sampling can either horizontal or vertical depending on estimate to be done for diameter (or basal area) or height.

Horizontal sampling: In horizontal pointsampling aseries of sampling points are selected randomly or systematically distributed over the entire area to be inventoried. Trees around this point are viewed through any angle gauge at breast height and all trees forming an angle bigger than the critical angle of instrument are counted

Point sampling: The circles in figure represent cross section of the trees at dbh and lines indicate critical angle of instrument from sample point. Even all the trees of same diameter are not counted tally being far away from the sample point. Similarly, from a sampling point a bigger tree is counted while smaller tree is not counted. Thus inclusion of trees depends upon size of trees and their distances from the sampling point. The number of trees counted when multiplied by a constant factor which isdependent on the size of the angle, gives basal area per ha.

Point sampling through wedge prism: Wedge prism is a wedge shaped piece of glass. Rays of light passing through the prism are bent depending on the critical angle of the prism. When a tree is viewedthrough a prism at breast height at right angle to line of sight andsimultaneously seeing the trunk of the tree directly from over the prism, it will be seen that the portion of the tree viewed through prism is displaced sideways depending upon the critical angle of the prism. Theimageof the tree is through prism is found figure.

1. It may overlap the tree stem sighted directly to lesser or greater extent (tally)
2. It's one edge may just touch the tree stem sighted directly, or (half tally)
3. It may be separated from the tree stem sighted directly by clear gap. (Non tally)

Basal area per ha (m^2 /ha) = total number of tally trees xbasil area factor of wedge prism

Point sampling through Spiegel Relascope: The construction of the Relaskope was initiated by the discovery of angle-count sampling (ACS) in 1947, a method which determines basal area density in forests by a simple counting method. The Relaskope automatically corrects for any inclination in the line of sight, making it possible to easily find the stand basal area in square meters per hectare either at breast height (1.3 m above the ground) or any other height. This is amultipurpose instrument used in point sampling.

Vertical point sampling: The standing at one point, the observer presses the button to release the pendulum. It assumes again a vertical position resulting in automatic adjustment of the variable band width since the graduations have been reduced by the factor of the cosine of the slope angle. The measuring band representing different critical angles or basal area factors are magnified through a lens, projected on a mirror and appear in the lower half of the field of vision. The width of band with the peep hole produces the angle. The observer then makes a sweep of the surrounding trees and compares the breast height diameter of each tree with the band. The tree that appears bigger than the chosen scale (band width) at breast height is a tally tree. Trees appearing smaller than the chosen scale arenon-tally trees. The basal area is obtained by multiplying the number of trees by the basal area factor of the band used.

LOCAL FORESTS VISIT FOR DETERMINATION OF SITE QUALITY

Objective: To determine the site quality to estimate the growth and yield of the forests

Site quality is a measure of relative productive capacity of a site forparticular species. In some countries it is expressed as site index. It is complex of physical and biological factors of an area that determine what forest or other vegetation it can support over a period of time. A knowledge of site quality is prerequisite is for prediction of growth and yield of a stand. Site quality can be evaluated by measurement of either site factors or vegetative characteristics.

Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Dendrometer

Procedure: Site quality can be evaluated by measurement of either site factors or vegetation factors

Site factors: Site factors areeffective climatic, edaphic and biotic factors which influence the growth and development of forest or other vegetation in a locality. It is difficult to quantify the all the factors together in a single index for productivity assessment. There are some of the indexes are based on climatic and vegetation factors as proposed by Paterson.

C.V.P. index (I) = $(Tv / Ta) \times (PxG/ 12) \times (E / 100)$

Where CVP index is climate, vegetation and productivity index; Tv and Tq are maximum and minimum temperatures; P is precipitation in mm; G is growing period in months and E is a measure of evapotranspiration.

This index is too broad as it does not take intoaccount thecharacteristics of soil and, topography, biotic and other environmental factors.

Vegetative factors: The other important factors can be useful for site quality assessment is vegetative factors which may indicate specific qualities of a site The characteristics of vegetation which could serve the purpose for in the form of natural vegetation in the area or volume, basal area diameter or height of the trees of dominate vegetation in the area.

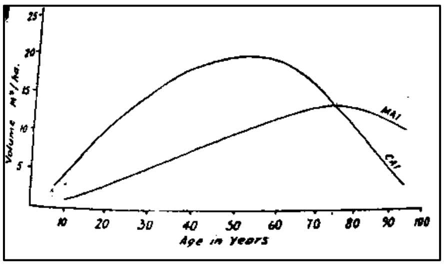
Plant Indicators: These are plants are specially herbaceous or shrub species which indicate the site of aperticular soil condition or tree species or forests. Many forests are coreclated by plant indicators e.g. in Canada and Finalnd but not universal. It holds good in simple composition of forests, require considerable ecological knowledge, and lower vegetation limited to upper layer of soil while trees do require lower horizon which not reflected in herbaceous vegaetaion.

Tree Characterstics: The most important charcaterstic sof trees which reflect the productivity of the sitev are its volume, basal area, diameter, and height. In western countries site index is determined with reference to height of the trees.

GROWTH POTENTIAL OF A FOREST

Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Dendrometer 4. Increment bore

Procedure: The pattern of growth in even aged forest satnd in term sof volume increment can be depicted by cai (Current annual increment) and mai (Mean annual increment) curves. After some yerars of planting the increment of a styand increases, reaches paek and falls off thereafter can be seen in cai curve. This curve represent annual artae of increment in volume at any given point of time. The average rate of annual increment shown by mai. When ami reaches paeks it cross to cai and point is called point of maxium average rate of inctrement which a perticular species can achieve in a perticular site. This point also called forester's maturity point. So a stnd to felled theoretically at that point and replanted gain maximum production in perpetuity.

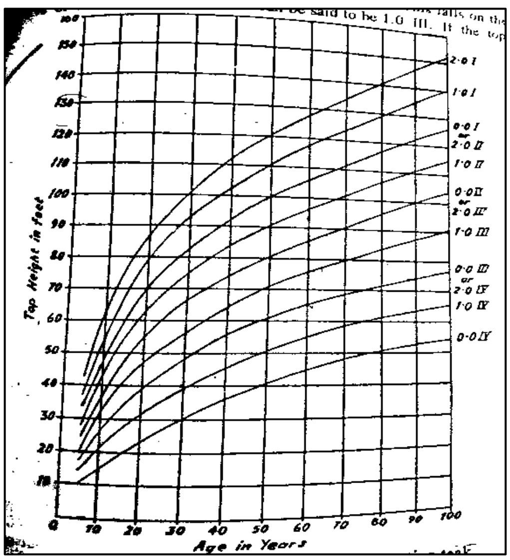


The important point isthat this point varies with species. Further maximum mai is thev maximum average rate of volume production which can be attained by a given site , irrespective of the time of culmination and it is this feature which is the basis of yield cals system.

Thus stand of yield class 14 has a maximum mai of about 14 m3/ha. Such classification is of limited use as it can caonly be use to categories of crops which have already reached their mai. Thec logical sequence for assessing yield class is thus would be to measure top height, convert it to local voume atble and derive mai. Yield calss table obtained through top height and age of the stand above is term as general yield class. Diameterv also reflect yield but affected by stand density. So it is not used for site quality differentaiation while height is laest affected by stan d density atken as best linear measurement for site quality.

The relationship of tree height and age has been used in most counytries as a measure of site quality called site index which is average height of dominat and co dominat trees will attain at key ages of 50 or 100 years. Previously till 1930 in India average height used to be atken for voume of stand but later top height calculated crossponding to 250 biggest daimeters taken in to account and delimted the yoeld calsses by different methods.

Strip height method based on Baur's method: It requires plotting of volume per acre against age of each plot and than drawing a limiting curve to delimit the upper nad lower boundary of the data. The sapc ebetewen two limitiung lines is the divided in to strips of equal width harmonised curve following the trend of the limiting curves. These stripd represent different site quality classes. Usually three site quality classes differentiated but species like sal with extensive geographical distribution has IV site quality classes. The intermediate site quality clasess (Fractional site quality) are diffrentated as I/II or II/III etc



British Forestry Commission Mthod (BFC): BFC rerjected Bur's method as its limiting curves are based on few highest and lowes points. BFC proposed from each plot of 450 yresa of age three stems of approximately mean heif=ht will be seslected subjectec to stem analysis and mean height curve is preaored. The ragne of height is didbvided into 10 ft divisons represting quality class. On the basis of height of 5o years the plots of this age and over then allotted their qualities and their average mean heighth at adifferent ages ias calculated by dividing the total maen heighthat different ages by total number of plots in that class. These average mean heights are plotted against their ages and a smooth curve is drawn to obtain the mean quality curves.

FRI Method: This is compromise method between above two methods. In this methos , while the strips of the site quality clsses are made , these strips wiwth points in them are plotted on separate papers and mean curve is drawn. The procedure of the method as described as top height of all plots are plotted on a square paper against their top nagaes and poinst crores ponding to successive measurements of each plot are joined by straight lines. This scattered diagram is then divided into four or five abritaory strips from top to bottom. Fractional site quality: Site quality expressed as a decimal subdivision of height range of half a quality class, the figure running from 0.0 to 2.0within the whole quality class. A knowledge of quality of the site is a prerequisite for prediction of growth and yield of stand with the help of the yield tables because they give the information of the by quality classes.

VOLUME MEASUREMENT METHODS IN SAMPLE PLOT

Objective: measurement of tree volume in sample plot is important task specially by the method which requires minimum felling of trees andmaximum precision in estimate of sample plot volume.

Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Dendrometer

Procedure: In sample plot all trees are not measured for all attributes except diameter. On the basis of measurement of sample trees, volume of the sample plot is computed. Different methods have been developed in different countries by different workers. The important includes

Arithmetic mean sample tree method-this method consists in determining the volume of a mean basal area tree which when multiplied by the number of trees (N) of the sample plot gives the volume (V) of the sample plot by the following formula

V =N x v where v is volume pf the mean basal area of the tree

The method is simple and easy to apply because a single tree is measured. But this method presupposes that the arithmetic mean basal area tree has also the mean volume of stand, which is hardly true because there is different form- heights and consequently different volume.

One-inch diameter class method or Hossfeld's method- In order to overcome the defect of the arithmetic mean method Hosssfeld suggested that the stand may be divided into as many small groups as there areone-inch diameter classes so that in that small group that assumption that mean basal area tree I mean volume tree may hold good. After classifying the trees of the stand one inch diameter classes, a mean basal area tree is selected in each class and its volume computed. Then volume of the sample plot or the stand is given by the formula: $V = n1v1+n2v2+ n3v3+\text{-------}n_nv_n$

Were v being the volume of the sample plot or stand;

N1, n2, --- are the number of trees in one-inch diameter classes

V1, v2---- are the volumes of the men basal area trees in each of those classes

Huber's method: In order to avoid the drawbacks of Arithmetic mean and One-inch diameter method s, Huber suggested that groups may be formed of equal number of diameter classes to reduce the number of groups and consequently the number of sample tree. Thus this method is compromise between the two method described earlier. After grouping, the mean basal area tree for each group is selected and its volume computed. Then the volume of the sample plot is calculated as in the previous method. This method has also the defect that sample trees represent varying number of trees in each group.

Urich's method In order to remove the defects of Hossefeld and Huber method, Urich suggested that the groups should be so formed that that they May have equal number of trees and that same number pf sample trees should be selected from each group, then the volume of the sample plot or stand (V) is calculated by the formula

V= (Total volume of the sample trees x Total basal area of the stand)/ Total basal area of the sampled trees

Hartig's method- In the previous method, even though the sample trees reprinted equal number of trees of each group, they represented different volumes. Therefore, Hartig suggested that the groups should be so made as to have equal volume. As this requires previous calculation of volume, he suggested that groups should have equal basal area. As volume is directly proportional to basal area. After making these groups, the mean basal area is calculated. Then two trees of this basal area are selected from each group and they are felled for computing volume. Then the volume of each group is found by the formula:

V= (v x S)/ s Where V is the volume of the group, v is the volume of the sample trees, S is the total basal of the group, and s is the basal area of the sample trees

The volume of the whole stand is obtained by totalling the group volumes.This method is subject to the same erratic fluctuations as those to which all the sample tree methods are liable because the mean basal area trees, however carefully chosen, differ in form and height and so in volume. Then this method increases computation work by requiring calculation of the volume of each group first to arrive at the total volume of the stand. However, since the sample trees represent small basal areas, the absolute error in each group becomes equal and the chances of their cancelling out becomes higher. In view of this probability of higher degree of accuracy, this method is used in temporary sample plots.

Blocks method – Block proposed a method of group formation in a stand based on an entirely different principle. He argued that for the purposes of successive measurements of a plot, it is very important to consider the volume of different trees separately sinks the lower diameter classes almost entirely disappear in the course of a few thinning. He therefore prescribed the formation of a number of small group depending on the total number of the diameters per hectare. The groups are to be formed from the highest to the lowest diameter i.e. in descending order. This method has been used by the Forest Research Institute, in Dehradun for computation of volume and other crop parameters of permanent sample plots after certain modifications introduced by Howard in 1921.In this modifications, the volumes of sample trees are calculated by the form factor method or Prussian Institutemethods which is described later in this chapter. The following table gives the number of diameters per ha and the number of groups made in each with number of diameters in each. It should be noted that each tree will have two diameters.

The method consists of the following steps:

1) Diameters are classified into 2cm diameter classes. The two diameters of a tree are considered independently and are arranged in descending order.
2) Number of diameters are converted to per hectare figure by dividing by plot area.
3) Groups are made according to the above table. The diameters of the same diameter class may go into two or more groups for this purpose.
4) Diameters for each group are determined by multiplying by plot area.
5) Mean diameter of each group is determined from mean basal area of the group.
6) Based on the measurement of sample trees, height/ diameter and form factor/ diameter curves are drawn.
7) Mean heights and mean form factors are read from the above curves for the mean diameter of each group.
8) Volume of each group is calculated by the formula, Volume = Basal area of the group x Mean height of the group x Mean form factor of the group.
9) Total volume of the groups is halved to get the volume of the sample plot.
10) Mean diameter of the crop so calculated from total basal area and mean height is obtained by reading the value of height for the mean diameter from the height diameter curve.
11) Top diameter corresponding to 250 biggest diameters per ha is calculated through basal area of this diameters. Height corresponding to this diameter as read from the height/ diameter curve is the top height.

METHODS OF DETERMINE PAST GROWTH OF STAND

Objective: Past growth measurements of stand gives the estimate of yield and site condition of existing forests. The usual method for this to take repetitive data over the years.

Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Dendrometer

Procedure: Permanent sample plot is laid to record periodic data for determination of past growth. The two common methods used for this purpose includes

1. The method of control
2. Continuous forest Inventory method

The method of control: This method I originally devised byGournad in France and later adopted by European countries. This method requires complete enumeration of total stand but possible only for small stand. so I large forestsample plots are laid. At initial inventory entire sample plot is enumerated and trees are classified by diameter classes. Then record of all diameter classes removed or volume of trees removed till next inventory is also recorded. The total volume of different diameter classes is calculated by local volume table and added up to obtain the volume at each inventory.

I= V_2 V_c- V_1 where, I is periodic growth of the stand

$V_2$is volume of the sample plot or stand at the second inventory

Vc is the volume of the trees removed during the period intervening between the first and second inventory

V_1 is volume of the sample plot or stand at the inventory

The diameter increment by diameter classes under the method of control is calculated by an elaborate computation method which takes into account the number of trees rising into diameter class, trees remaining stationary in the class, and the trees going out of the class in successive inventories. Increment in each diameter class I calculated as

I= DR/ DE x C and average periodic increment for all trees = ∑DR/ ∑DE x C

Where, DR stands for Double rising which means the sum of trees rising out and rising into a class.

DE stands for double effective which is sum of trees in first and second inventories after correction of the trees removed;

C is width of diameter class Or specific diameter class number of trees rising into the class is calculated as follows

Tree rising = number of trees in second inventory – number of trees in first inventory + number of trees rising out of the class.

Continuous Forest Inventory Method (CFI): This is American modification of European method to control to serve two specific needsof (i) use of sample plots and use of modern computing machine. In this methodrepresentative sample plots are systematically distributed and periodically surveyed instead of having total area enumeration by diameter classes. While the plot should be representative of the whole forest, they should be representative of cutting, mortality and growth etc., of the entire forest. These plots will also under go same silvicultural treatments as rest of the forests. The linear increments plots laid in certain forests in India are examples of CFI. Generally sampling intensity ranges from 0.03 to 0.1 per cent using circular plot of about 0.50 ha to 0.08 ha. Center of the plots marked on the ground with wooden/ aluminumstack and trees are measured numbered and painted cross mark. Diameter, height, volume of each tree so marked is measured at each inventory carefully and recorded. From the study of growth in sample plots, growth of thousandbetween the two inventories is estimated. CFI can give more reliable result with respect to mixed forests. They also provide data for simulation studies.

METHODS OF YIELD TABLE PREPARATIONS

Objective: Yield table preparation is one of tool of estimation of growth and yield of a stand. Unlike volume table which yield table is dynamic and forecast the future yield. Yield of forests depend upon several factors such as its structure, growth, density, the reproductive capacity of the site, etc. Stand structure knowledge is important for yield determination.

Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Dendrometer

Procedure: Yield table is a tabular statement which summarises on per unit areas basis all theessential data relating to the development of a fully stocked and regularly thinned even aged crop at periodic intervals covering the greater part of useful life. It gives different parameters of a crop such as number of trees, crop height, crop diameter, crop basal area, volume of standing crop, volume removed in thinning, mai, cai etc. It gives all quantitative information development of a tree crop.

Primary data comprises volume of main crop, thinning volume, final yield and accumulated yield. Secondarydata includes crop averages for diameter, height, number of stems per unit area, crop basal area, form factor, m.a.i and c.a.i.

Besides yield table also give information of top height by site quality and age, spacement table for both height & diameter v/s site quality; number of trees per unit area by crop diameter and sit quality; Normal growing stock of stem timber volume and stand table.

Kinds of yield table: Yield tablesare grouped on the basis of grade of thinning and expression of out turnin volume or value.

On the basis of number of grades of thinning used:

- **Single Yield table**- It is a yield table in which parameters have been given only for one grade of thinning which usually c grade.
- **Multiple yield table**- These are yield table in which data is given for different grades of thinning

On the basis of volume or value given:

- **Volume yield table**- It is a yield table which express outturn in termsof volume
- **Money yield table**- It is a yield table constructed from volume table and expressed in termsof money.

Preparation of Yield table Preparation of yield table involves several steps and documentation of all contents mentioned above. The important steps are incudes

First construct top height and top age curve by site qualities. After proper harmonization of scattered points curve line plotted and site quality marked. Second steps crop age and mean crop basal area per hacter figure of plot measurements are grouped separately for each site quality at 5 or10-year age class interval and average is calculated. On the basis of comparison of actual and derived value number of trees accepted or rejected per hectare. Thirdly, for each site quality the main crop data of acceptable measurements are grouped on 5 or 10-year age classes with all parameter mentioned earlier in contents. The average of each age classes are plotted against average crop age and smooth curve draw for each site quality with necessary adjustment. Number of trees per hectare x average basal area= basal area per hectare

Basal area per hectare x crop height x form factor= volume per hectare.
The value against the 5 or 10 age class is read from these curves and tabulated. Curves are plotted for fractional site qualities as well and tabulated. Data on subsidiary crop is also similarly curved atabulated.

Another method of yield table preparation by linear regression equations fitted between timber volume as well as total wood volume against the product of basal area andcrop height. Linear regression is also fitted between

(a) Crop height and top height
(b) Crop diameter and crop height
(c) Number of trees per hectare and crop diameter
(d) Crop height of subsidiary crop acrop height of main crop
(e) Limiting curves are drawn for site quality. From these curves top height is obtained cross ponding to each decade for each site quality.
(f) For each 10-year value of crop height and crop diameter are obtained d by regression of crop height/ top height and crop dia meter / crop height. Number of tees I obtained from the regression of number/ crop diameter. From values of number and crop diameter, basal area per hectare is obtained by the formula BA= $\pi D^2/ 4 \times N$
(g) The product of basal area and crop height is used to get timber volumes as well as total wood volume from the regression obtained earlier.

WOOD DENSITY

Objective: To estimate the density of wood sample. Above ground and below ground biomass estimation is an important task in forest inventory and yield prediction. For this purpose knowing the density of woody material also important.

Material required:- Wood Sample, weighing scale, measuring tape/vernier scale

Procedure: The density (ρ) of wood defined as mass (*m*)/weight of a unit volume (*V*) of the material and is expressed as kg/m^3 (or lb/ft^3). $\rho = \frac{m}{V}$

Mass can be measured by placing the wood specimen on weighing scale and reading is noted in grams or kilo.

Methods of calculating Volume – By geometry, and By water displacement

By geometry- Calculate volume of block of wood by actually measuring its length (L), width (W) and thickness (T) in mm or cm and multiplying them.

Volume: L × W × T

Calculate the volume of a cylindrical shaped specimen by dividing the diameter by two to calculate the radius. Square the radius and multiply the result by 3.14, and then multiply your product by the length. Thus calculated volume by determining the actual measurements will be in mm^3 or cm^3, etc.

By water displacement- For less defined shapes, volume can be determined by water displacement. Volumes of liquids such as water can be readily measured in a graduated cylinder.

To use the water displacement method, specimen is inserted into a graduated cylinder partially filled with water. The specimen's volume occupies space, displacing liquid and raising the water level. The difference between the two volumes, before and after the object was inserted, is the object's volume.

PREDICTION OF BIOMASS AND VOLUME IN FOREST STANDS

Objective: Modelling in forestry used to predict the biomass/volume of a tree from easier-to measure dendrometric characteristics such as tree diameter or height, are key factors in estimating the contribution made by forest ecosystems to the carbon cycle

Material required: Measuring tape, weighing balance, axe, wood-saw, and oven, sample bags

Biomass estimate is to develop an allometric equation that will allow us to estimate the mass of a tree from a few simple measurements of it and then to apply this equation to the trees in a forest. The term allometry is defined as "the measure and study of relative growth of a part in relation to an entire organism or to a standard". It is based upon a principle first describe by Galileo Galilee in the 1630's

If we call biomass B and diameter D, second definition means that there is a coefficient a such that:

$$\frac{dB}{b} = a\frac{dD}{D}$$

which integrates to a power relationship: $B = b \times D^{a}$ Parameter 'a' gives the allometry coefficient (proportionality between relative increases), whereas parameter b indicates the proportionality between cumulated variables. It may be necessary to add a y-intercept to this relation that becomes B = c + bDa , where c is the biomass of an individual before it reaches the height at which diameter is measured (e.g. 1.30 m if D is measured at 1.30 m). In Simple words Regression is a method to mathematically formulate relationship between variables that in due course can be used to estimate, interpolate and extrapolate. Suppose we want to estimate the weight of trees, which is influenced by height, DBH, wood density, form factor, tree management (pruning/thinning) etc. Here, Weight is the predicted variable. height, DBH, wood density, form factor, tree management are predictor variables.

For construction of regression equation i.e. allommetry, we requires to harvest trees destructively and measured component wise for biomass and volume.

Biomass measurement: All live trees with DBH from 5 cm and above in the sample plots will be measured. The information to collect include: i) tree species ii) DBH of trees and iii) Tree height. The destructive sampling of tree species for biomass quantification methodology is taken from FAO, 2012.

The suggested steps for measurement are:

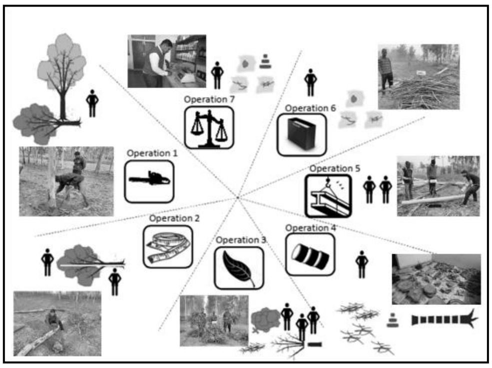
1. Identifying tree species (tree name) should be done first before starting the measurement of DBH; Laborers may also assist in clearing ground vegetation for tree access.
2. Using a 1.3 m pole, mark measuring position for DBH measurement; (See box 1)
3. Record all information collected (number of stumps; buttress diameter; height of buttress etc) and irregularities if any.
4. Enter the data on DBH in excel spread sheet and group DBH data of trees into DBH class. The interval of DBH class is 10 cm, and DBH classes are: 5 – 15 cm; 15 – 25 cm; 25 – 35 cm; 35 – 45 cm; 45 – 55 cm; 55 – 65 cm; 65 – 75 cm; etc.
5. Select randomly the sample trees in each DBH class in the sample plots.
6. After selection of sample trees for each DBH class, use chain saw to cut down the tree at its base following logging procedures.
7. Once the sample tree is cut down, accurately measure:
    a. Diameter at stump; DBH at 1.37 m;
    b. Total tree height (from the stump to the top of the crown).
    c. Length of tree bole - from the stump to the first main branch;
    d. Length of tree bole - from the stump to the point where diameter becomes 10 cm;
    e. If tree with buttress, measure diameter and height of the buttress
8. Separate the cut trees into different parts (e.g. bole, branches and leaves).
9. Use scale to measure immediately the weight of stem, branches, leaves and buttress if tree with buttress.
10. Carefully record all information on destructive measurement of sample trees in the sheet.
11. Figure provides complete overview on selection of trees to component-wise measurement of biomass.

Tree diameter (cm) Girth of the trees at breast height of 1.37 m (over bark) was measured with the help of measuring tape in centimetre (cm). For measuring girth of the trees, observations such as collar girth (15 cm above ground surface), girth at breast height (1.37m), mid girth and top girth were recorded in cm. In case of stem log, base girth, mid girth and top girth was recorded separately to calculate volume of tree (m^3). The girth was converted to diameter by using following formula:

$$DBH\ (cm) = \frac{GBH\ (cm)}{\pi}$$

Whereas DBH: diameter at breast height & GBH: girth at breast height at 1.37 m on ground

Tree height (m): Heights of selected trees were measured with the help of measuring tape in metre (m). Trees height measured from harvested basal part to longest tip of the felled tree on ground.



Destructive sampling of biomass & their measurement in 7 different operations. Operation 1: site preparation and felling of the trees; operation 2: measurement of felled trees stem profile, marking for cross-cutting; operation 3: stripping of leaves; operation 4: component wise biomass separation; operation 5: weighing of logs; operation 6, sampling of branches; & operation 7: sample weighing and oven drying in laboratory

AERIAL PHOTOGRAPHS IN FOREST INVENTORY

Objective: Aerial remote sensing or aerial photography is most common form of remote sensing used in forestry for general worksand forest measurements specifically. Thedetailed study of any forest area in limited space can be done by this method for inventory but now the technique is modified with time for satellite imaging & software development

Materials required: 1. Measurement Tape, 2. Tree Caliper and 3. Aerial photographs, Stereoscope

Procedure: Aerial photography provides images on a photographic film or paper.Aerial photograph or imagery is prospective projection of the earth's surface while map is its orthographical projection. Aerial photographs are actual image of the object on the earth and their scale varies with terrain and place. It gives three dimensional view of earth's surface and objects. Aerialphotography has to be studied and interpreted under the stereoscope and/ or with certain aids and instruments.

Classification of Aerial photo graphs: On the basis of different parameters aerial photo graphs are classified as follows

On the basis of film used

- Panchromatic black and white photograph
- Infra-redblack and white photograph
- Colour photograph
- Infra-red colour photograph

On the basis of device used

- Single lens photograph
- Multispectral photographs
- Multispectral imagery

On the basis of scale of photograph

- Large scale photograph- 1:50000 to 1:20000, Further divided in very large scale (1:5000 to 1:10000), large scale (1:10000 to 1: 20000)
- Medium scale photograph- 1.20000 to 1: 40000
- Small scale photograph- 1:40000 to 1:70000

On the basis of position of optical axis of camera

- Vertical photograph
- Oblique photograph

Identification of Object: In photo interpretation involves first identification of object. This is done by following pictorial elements

Tone – it is distinguishable shade variation from white (1) to black (10) in crowns of trees caused by differential reflection of light. Different species has different tones e.g. In western Himalayas chir, blue pine, deodar, oaks, fir and spruce have respectively light to darker tones. However, in practice, the use of tone in identifying species is complicated by several factors such as location of the sun, aspect on which the tree is growing in the hills, phenological characters, ageof the leaves, camera, photographic material used and the developing and printing process adopted.

Size- The sizeof the crown of mature trees as well as their heights often give indication for identification of certain species particularly when tone, shape and other pictorial element may not differentiate them from other species.

Shape of the crown – Though the trees of different species have distinctive shapes when viewed horizontally and so can be identified on easily on that basis from the ground, the problem is not so simple when viewed form air particularly ina vertically photograph.

Shadow - Shadows of the trees falling on ground help in the identification of species as they give an indication of the shape of the crown. But this depends upon the time of photography and the direction of flight.

Texture – Texture is defined as the frequency of change and arrangement of tones in an image. It describes the coarsenessor smoothness of images. It is produced by aggregation of unit features that cannot be seen individually.

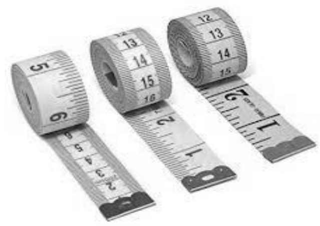
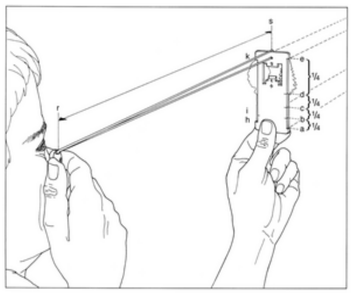
Pattern – Pattern relates to spatial arrangement of objects. The regularity and characteristic arrangement of objects gives them a pattern which is helpful in identifying them and is therefore a useful aid in photo interpretation.

Location – Location relates to the situation of objects with reference to site factors such as climate, topography, soil etc. as different species are found in different places under the influence of locality factors, location is helpful in identifying species.

STEREOSCOPY: Stereoscope is a binocular optical device for viewing overlapping images to attain a mental impression of three dimensions. They are not only useful in photo interpretation but are also useful in making measurements on photographs and transferring interpreted information on maps. Stereoscopy is defined as the science which deals with achieving three dimensional effects with binocular vision and the methods by which these effects are produced.To observe three dimensional effects, stereoscopic vision is required. Stereoscopic vision is the application of binocular vision in such a way as to enable the observer to view an object from two different perspectives. E.g. Two photographs of an object from two different camera positions so that a three dimensional model is formed into the mind.

Photogrammetry: After identification of species, the next important work that has to be done in connection with forest mensuration is the measurement of trees. The branch of science which helps in this is known as photogrammetry. It is defined as the art or science of obtaining reliable measurements and maps from aerial photographs.

IMPORTANT INSTRUMENTS FOR YIELD PREDICTION

		
Digital tree calliper	**Clinometer**	**Shunto clinometer**
		
Clinometer with gauge factor	**Abenys level**	**measuring tape**
		
Relascope	**Laser Relascope**	**Point sampling by clinometer**
		
Wedge prism application	**Marking of trees**	**Agroforestry platation**