M.Sc. GEOGRAPHY LAB MANUAL

1st Semester

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Pure & Applied Science Dept.
Geography

MIDNAPORE CITY COLLEGE

MIDNAPORE CITY COLLEGE

PRACTICAL COURSES

MA / MSc in Geography, Semester - I

PAPER GEO 195: HYDROLOGICAL RECHNIQUES AND SEDIMENTOLOGICAL ANALYSIS

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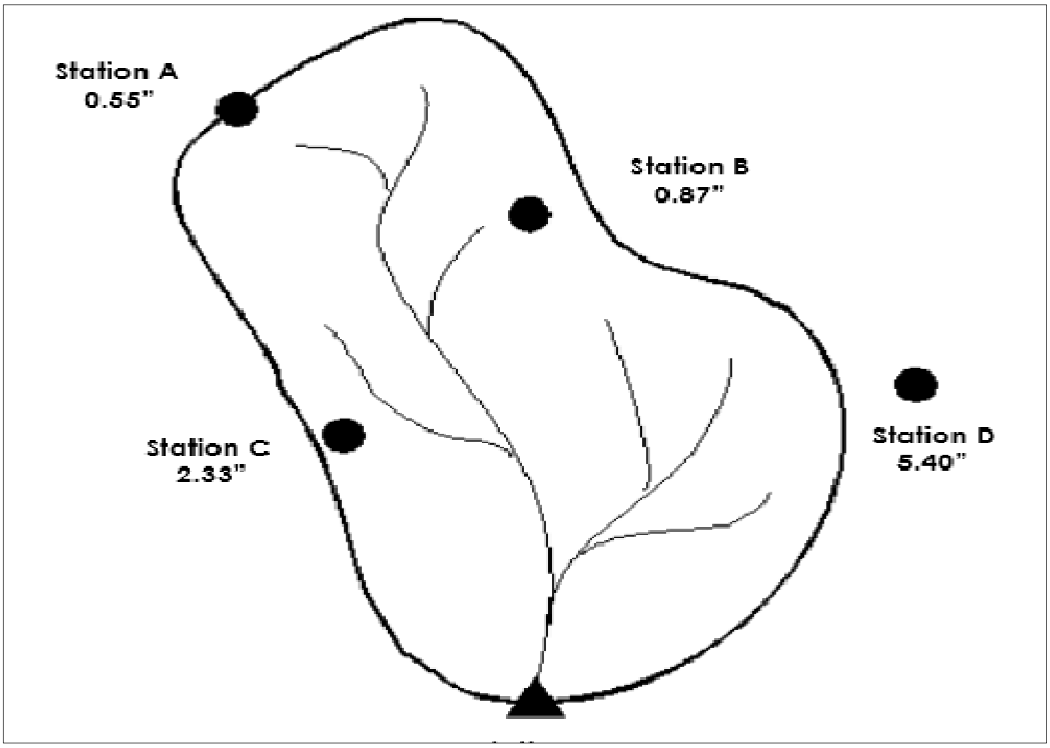
Unit- 195.1: HYDROLOGICAL TECHNIQUES

1. POINT RAINFALL ANALYSIS:

Watershed (also called drainage basin or river basin) is the land area where rainfall runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map called ridge. From the ridge, the direction of runoff flow when rain falls is opposite, that is, one is going outwards and the other is inwards as indicated by the arrows in Figure 1. Hence, a watershed is also called catchment area. With all other factors equal, the size of the river in the watershed is indicative of the watershed area, that is, the larger the watershed, the wider or bigger the river is. In a watershed, point rainfall analysis (PRA) is used to determine the mean amount of rainfall, and the spatial or areal distribution of rainfall.



A single point rainfall measurement is often not representative of the amount of rainfall falling over a very large catchment area. A network of rain gauges as shown in Figure 2 can provide a better representation of the true amount over a given large area. The data gathered in these various points are analyzed and converted to spatial or areal estimates using any of the following PRA techniques, such as: (a) arithmetic mean; (b) Isohyetal analysis; and (c) Thiessen polygon (NOAA, n.d).

a. Requirements:

1 pc Ball pen

1 pc scientific calculator

1 pair Scissors

2 pcs graphing paper

b. Procedure

Arithmetic Mean Method

This technique calculates areal rainfall using the arithmetic mean of all the points or areal measurements considered in the analysis.

$$\bar{R} = (\Sigma R_i)/n$$

Where: R Mean rainfall

Σ Summation sign which means add all individual observations

R_i Rainfall observation at point i

n Total number of rain gage observations

To illustrate the calculation of mean rainfall using arithmetic mean method, let us consider the gagged watershed in the above Figure. The step-by-step procedure is, as follows:

Step 1: Compute for the mean rainfall of the watershed in Figure 2 using Equation 1, thus:

$R = (R_A + R_B + R_C + R_D + R_E)/n$

= (0.55” + 0.87” + 2.33” + 5.40” + 1.89”)/5

= 2.21 inches x 25.4 mm/inch

= 56.1 m

Step 2: Interpret result

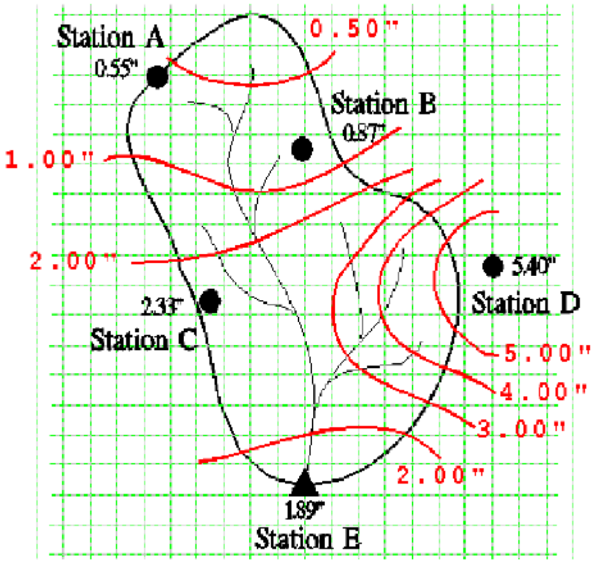
The interpretation would be “Therefore, the mean rainfall in the gagged 5,000 ha watershed using arithmetic mean method is 56.1 mm.

Isohyetal Analysis Method

This is a graphical technique which involves drawing estimated lines of equal rainfall over an area based on point measurements. The magnitude and extent of the resultant rainfall areas of coverage are then considered versus the area in question in order to estimate the areal precipitation value.

To illustrate the calculation of mean rainfall using isohyetal analysis method, let us consider again the gaged watershed in Figure 2 above. The step-by-step procedure is, as follows:

Step 1: trace on a graph paper the map of the watershed

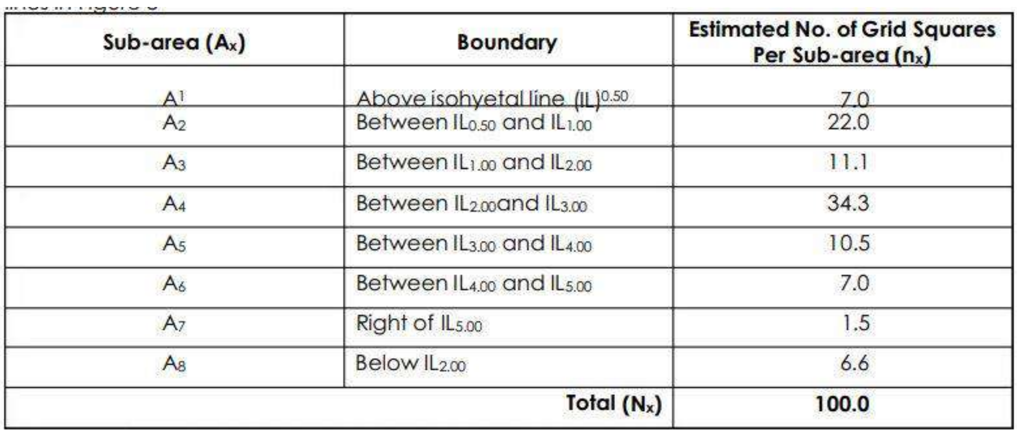


Step 2: Draw lines of equal rainfall.

The line of equal rainfall is called isohyets or isohyetal line, which is equivalent to a contour line for equal slope. In Figure 3 above, the isohyetal lines are colored red with corresponding rainfall magnitudes of 0.5 inch, 1 inch, 2 inches, 3 inches, 4 inches, and 5 inches. Note the distance of these isohyetal lines relative to the observed rainfall magnitudes of two adjacent stations. Note also that with these isohyetal lines the whole watershed is consequently sub-divided into several sub-areas.

Step 3:

For each sub-area, count the number of grid squares bounded by the isohyetal lines. For our example, the results are shown in Table below.



Sub-area (A_x)	Boundary	Estimated No. of Grid Squares Per Sub-area (n_x)
A^1	Above isohyetal line (IL)$^{0.50}$	7.0
A_2	Between $IL_{0.50}$ and $IL_{1.00}$	22.0
A_3	Between $IL_{1.00}$ and $IL_{2.00}$	11.1
A_4	Between $IL_{2.00}$and $IL_{3.00}$	34.3
A_5	Between $IL_{3.00}$ and $IL_{4.00}$	10.5
A_6	Between $IL_{4.00}$ and $IL_{5.00}$	7.0
A_7	Right of $IL_{5.00}$	1.5
A_8	Below $IL_{2.00}$	6.6
	Total (N_x)	**100.0**

Step 4:

Determine the supposed area per grid square of the graphing paper by dividing the known true area of the watershed by the total number of grid squares determined in Step 3, and Compute the average precipitation using the given formula.

$A_x = A_T/N_x$ Here, $A_T = 5{,}000$ ha

$N_x = 100.0$ grid squares

Therefore, $A_x = 5{,}000$ ha/100.0 grid squares

= 50 ha/grid square of the graphing paper

Therefore, every grid square on the graphing paper is equivalent to 50.0 ha in actual area of the watershed. With this information, we can now solve for the actual area of the sub-areas A_1 to A_8

Step 5:

Determine the actual area of each sub-areas A_1 to A_8 using the following Equation,

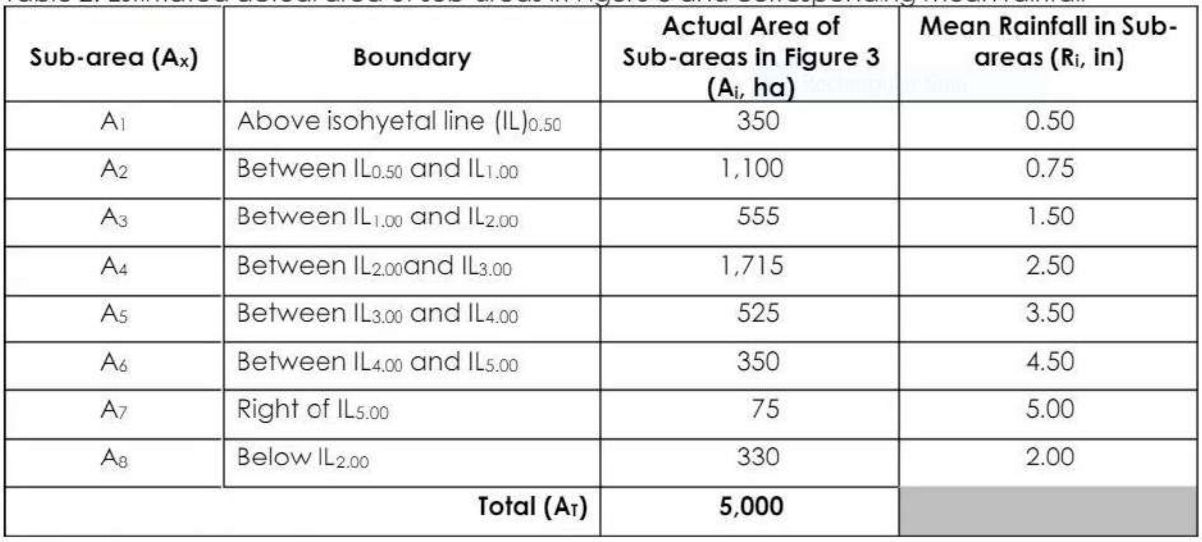
$$A_i = (Ax)\,(nx)$$

Where: A_i Actual area of sub-area i

A_x Supposed area per grid square of the graphing paper

n_x Number of grid squares bounded by the isohyetal lines

Table 2. Estimated actual area of sub-areas in Figure 3 and corresponding mean rainfall



Sub-area (A_x)	Boundary	Actual Area of Sub-areas in Figure 3 (A_i, ha)	Mean Rainfall in Sub-areas (R_i, in)
A_1	Above isohyetal line $(IL)_{0.50}$	350	0.50
A_2	Between $IL_{0.50}$ and $IL_{1.00}$	1,100	0.75
A_3	Between $IL_{1.00}$ and $IL_{2.00}$	555	1.50
A_4	Between $IL_{2.00}$and $IL_{3.00}$	1,715	2.50
A_5	Between $IL_{3.00}$ and $IL_{4.00}$	525	3.50
A_6	Between $IL_{4.00}$ and $IL_{5.00}$	350	4.50
A_7	Right of $IL_{5.00}$	75	5.00
A_8	Below $IL_{2.00}$	330	2.00
	Total (A_T)	**5,000**	

Step 6: Estimate the mean rainfall in the watershed using following Equation.

$$\bar{R} = [\Sigma(R_i)(A_i)]/A_T$$

Where: R Mean rainfall in the watershed

R_i Mean rainfall in sub-area i

A_i Actual area of sub-area i

A_T Total area of the watershed

Using Equation 4:

$$\bar{R} = \frac{[(R_1)(A_1) + (R_2)(A_2) + (R_3)(A_3) + (R_4)(A_4) + (R_5)(A_5) + (R_6)(A_6) + (R_7)(A_7) + (R_8)(A_8)]}{A_T}$$

Substituting values from Table 2:

$$\bar{R} = \frac{[(0.50'')(350\text{ ha}) + (0.75'')(1{,}100\text{ ha}) + (1.50'')(555\text{ ha}) + (2.50'')(1{,}715\text{ ha}) + (3.50'')(525\text{ ha}) + (4.50'')(350\text{ ha}) + (5.00'')(75\text{ ha}) + (2.00'')(330\text{ ha})]}{5{,}000\text{ ha}}$$

= 10,567.5 ha-inch/5,000 ha

= 2.11 inches x 25.4 mm/inch

= 53.6 mm

Step 7: Interpret results.

“Therefore, the mean rainfall in the gagged 5,000 ha watershed using the isohyetal analysis method is 53.6 mm

Thiessen Polygon Method

The Thiessen polygon method is another graphical technique which calculates station weights based on the relative areas of each measurement station in the Thiessen polygon network. The individual weights are multiplied by the station observation and the values are summed to obtain the areal average precipitation. To illustrate the calculation of mean rainfall using Thiessen polygon method, let us consider also the gagged watershed in above Figure. The step-by-step procedure is, as follows:

Step 1

Construct polygons by drawing a line connecting all two adjacent rain gage stations.
These connecting lines are shown as dotted red line in the following Figure.

Step 2

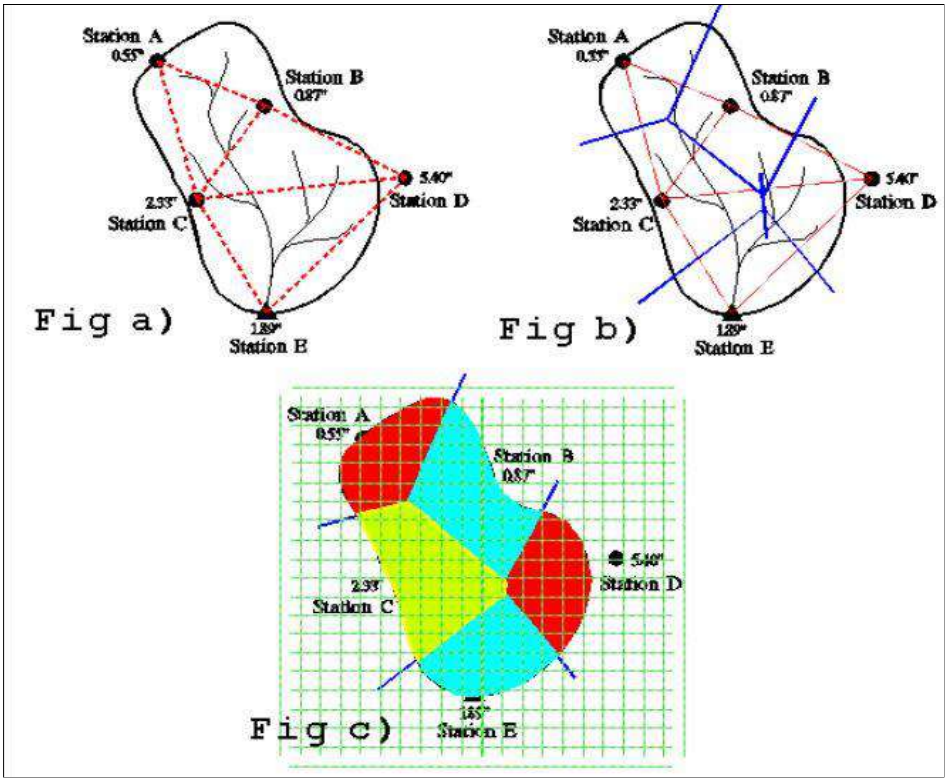
Bisect the sides of the polygon. These bisecting lines are colored as blue in the following Figure. Dotted red lines bisected by blue lines to form polygons covered by each station.

Step 3

Trace Figure b on a graphing paper. Then count the number of grid squares covered by each polygon.

Table 3. Estimated number of grid squares per polygon in Figure 6

Polygon (P_x)	Estimated No. of Grid Squares (n_x)
P_A	17.6
P_B	22.8
P_C	24.2
P_D	17.0
P_E	18.4
Total (N_x)	**100.0**



Step 4

Determine the supposed area per grid square of the graphing paper (A_x) using following Equation.

$$A_x = A_T/N_X$$

$$A_x = 5{,}000 \text{ ha}/100.0 \text{ grid squares}$$

$$= 50 \text{ ha/grid square}$$

Therefore, every grid square of the graphing paper is equivalent to 50.0 ha in actual area of the watershed. With this information, we can now solve for the actual area of the polygons in Figure.

Step 5

Determine the actual area of each polygon P_A to P_E using following Equation,

$$Px= (Ax)\ (nx)$$

Where: P_x Actual area of polygon x

A_x Supposed area per grid square of the graphing paper

n_x Number of grid squares of the polygon x

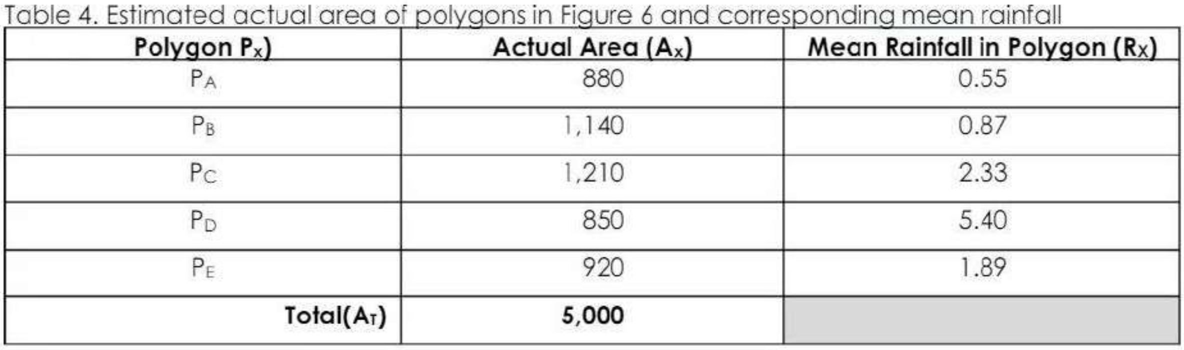
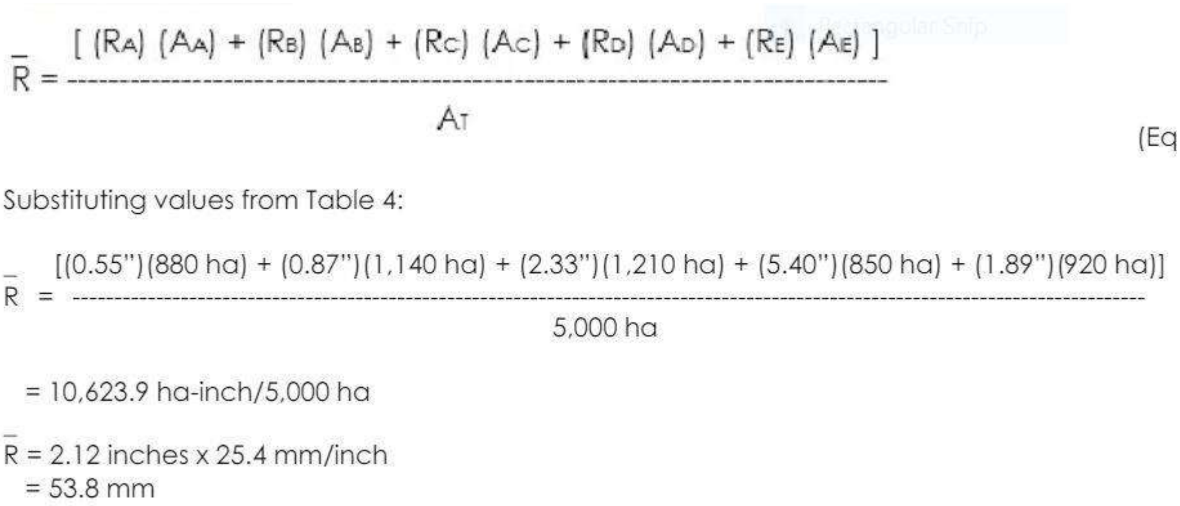


Table 4. Estimated actual area of polygons in Figure 6 and corresponding mean rainfall

Polygon P_x)	Actual Area (A_x)	Mean Rainfall in Polygon (R_x)
P_A	880	0.55
P_B	1,140	0.87
P_C	1,210	2.33
P_D	850	5.40
P_E	920	1.89
Total(A_T)	**5,000**	

Step 6

Estimate the mean rainfall in the watershed using following Equation



$$\bar{R} = \frac{[\ (R_A)\ (A_A) + (R_B)\ (A_B) + (R_C)\ (A_C) + (R_D)\ (A_D) + (R_E)\ (A_E)\ ]}{A_T}$$

(Eq

Substituting values from Table 4:

$$\bar{R} = \frac{[(0.55'')(880\ ha) + (0.87'')(1{,}140\ ha) + (2.33'')(1{,}210\ ha) + (5.40'')(850\ ha) + (1.89'')(920\ ha)]}{5{,}000\ ha}$$

= 10,623.9 ha-inch/5,000 ha

$\bar{R}$ = 2.12 inches x 25.4 mm/inch

= 53.8 mm

Therefore, the mean rainfall in the watershed is 53.8 mm.

Step 7 Interpret result.

The interpretation would be “Therefore, the mean rainfall in the gaged 5,000 ha watershed in the Thiessen polygon method is 53.8 mm.”

2. Estimating infiltration using infiltrometer and other field techniques. Drawing infiltration curve.

1.1 Infiltration:

Infiltration is the process by which water on the ground surface enters the soil surface. Precipitation falling on the soil wets down and it starts penetrating into the soil. Water restores to the formal level the soil moisture deficiency excess moving down by the gravity force through percolation or seepage to build up the water table. The water is driven into the porous soil by force of gravity. First the water wets soil grains and then the extra water moves down due to gravitational force.

1.2 Infiltration Rate:

The infiltration rate is the velocity or speed at which water enters into the soil. It is usually measured by the depth (in mm) of the water layer that can enter the soil in one hour. An infiltration rate of 15 mm/hour means that a water layer of 15 mm on the soil surface will take one hour to infiltrate.

In dry soil, water infiltrates rapidly. This is called the initial infiltration rate. As more water replaces the air in the pores, the water from the soil surface infiltrates more slowly and eventually reaches a steady rate. This is called the basic infiltration rate.

Table: Basic infiltration rates for various soil types.

Soil type	Basic infiltration rate (mm/hour)
sand	less than 30
sandy loam	20 - 30
loam	10 - 20
clay loam	5 - 10
clay	1 - 5

The infiltration rate depends on soil texture (the size of the soil particles) and soil structure and is a useful way of categorizing soils from an irrigation point of view.

1.3 Factors affecting Infiltration: Factors affecting infiltration depends on both meteorological and many soil properties. These are

i. **Texture**: The liquid moves very quickly in large pores of sandy soil than it does through small pore in clayey soil. Texture plays main role in susceptible of soil only when the organic matter is low.

ii. **Clay mineralogy**: Some types of clay may develop cracks as they are dry. These kinds of cracks may rapidly conduct water to the sub-surface once and the seal shuts down once the soil becomes wet.

iii. **Vegetation**: Soil covered with vegetation has grater infiltration than the barren land. Because of the bacterial activities, dense forest may have good infiltration rate than sparsely planted crops.

iv. **Physical Crusts:** Physical crusts from when purely aggregated soil are subject to the impact of raindrops and/or to ponding. Particles broken from weak aggregates can clog pores and seal the surface, thus limiting water infiltration.

v. **Soil Density:** A compacted zone close to surface restricts the entry of water into the soil and often results in Surface ponding. Increased bulk density reduces pore space and thus the amount of water available for plant growth.

vi. **Biological crusts:** Biological crusts can either increase or reduce the infiltration rate. This affects the infiltration rate on many other factors, including soil texture.

vii. **Antecedent Moisture content**: Infiltration mainly depends on the presence moisture content in the soil. When compare to first day the second day will have lesser infiltration rate because soil becomes saturated on the first day.

viii. **Human activities:** When vegetation was done or a grass covering barren land has the high infiltration rate. Whereas the other side the construction work, over gazing of pastures and playgrounds reduce infiltration capacity of the area considerably.

1.4 Methods of estimating infiltration:

The most common method to measure the infiltration rate is by a field test using a cylinder or ring infiltrometer and by Ponding methods.

i. Techniques of uses ring infiltrometer:

a. Equipment requirements:

i. Shovel/hoe

ii. Hammer (2 kg)

iii. Watch or clock
iv. 5 liter bucket
v. Timber (75 x 75 x 400)
vi. Hessian (300 x 300) or jute cloth
vii. At least 100 liters of water
viii. Ring infiltrometer of 30 cm diameter and 60 cm diameter. Instead of the outer cylinder a bund could be made to prevent lateral water flow.
ix. Measuring rod graduated in mm. (e.g. 300 mm ruler)

b. Procedure:

Step 1:

Hammer the 30 cm diameter ring at least 15 cm into the soil. Use the timber to protect the ring from damage during hammering. Keep the side of the ring vertical and drive the measuring rod into the soil so that approximately 12 cm is left above the ground.

Step 2:

Hammer the 60 cm ring into the soil or construct an earth bund around the 30 cm ring to the same height as the ring and place the hessian inside the infiltrometer to protect the soil surface when pouring in the water.

Step 3:

Start the test by pouring water into the ring until the depth is approximately 70-100 mm. At the same time, add water to the space between the two rings or the ring and the bund to the same depth. Do this quickly.

The water in the bund or within the two rings is to prevent a lateral spread of water from the infiltrometer.

Step 4:

Record the clock time when the test begins and note the water level on the measuring rod.

Step 5:

After 1-2 minutes, record the drop in water level in the inner ring on the measuring rod and add water to bring the level back to approximately the original level at the start of the test. Record the water level. Maintain the water level outside the ring similar to that inside.

Step 6:

Continue the test until the drop in water level is the same over the same time interval. Take readings frequently (e.g. every 1-2 minutes) at the beginning of the test, but extend the interval between readings as the time goes on (e.g. every 20-30 minutes).

Note that at least two infiltration tests should be carried out at a site to make sure that the correct results are obtained.

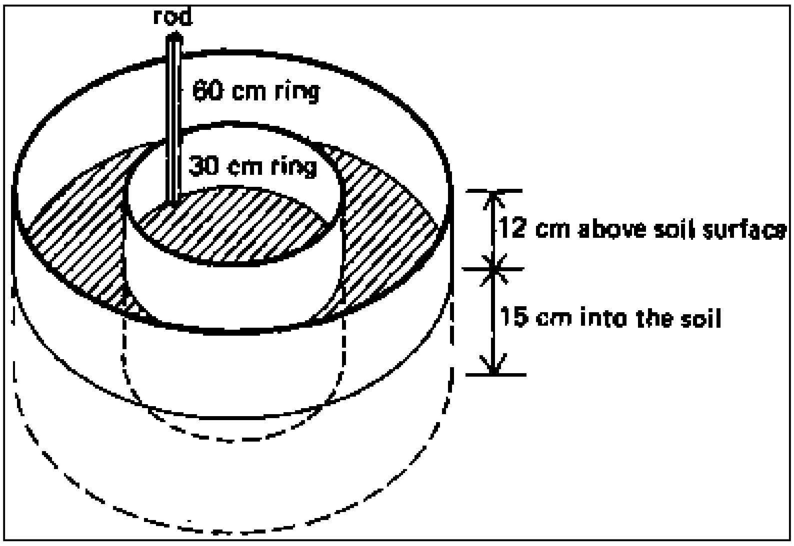


Figure: Infiltrometer

ii. Ponding methods:

Procedure:

Ponds can be created using bunds or dykes around an area on the ground surface and operated in the same manner and by using the same procedures discussed above for cylinders.

The ponding; method can be used in small basins and other larger ground surface areas to evaluate the infiltration rates of a larger fraction of the field. The disadvantage of this technique is that edge effects can be significant.

This problem can be overcome by giving special care to the sealing of the pond perimeter with compacted clay or installing a plastic barrier. The operational and data gathering procedures, including the forms for recording data, are the same as for cylinder infiltrometers.

The application of the ponding; technique to furrows requires a slightly different infiltrometer configuration. The total infiltration in a furrow consists of water moving laterally through the furrow sides as well as vertically downward. Bondurant (1957) developed a 'blocked' furrow infiltrometer which recognizes this special feature of furrows.

For silt and clay soils, the basic intake rate will generally be reached before the wetting fronts of adjacent furrows meet in the soil between furrows and the buffering is probably not necessary. In sandy soils, this may not be the case so the basic intake rate may be influenced by the soil moisture distribution after the wetting fronts meet. Thus, the buffering would be necessary to determine accurate readings.

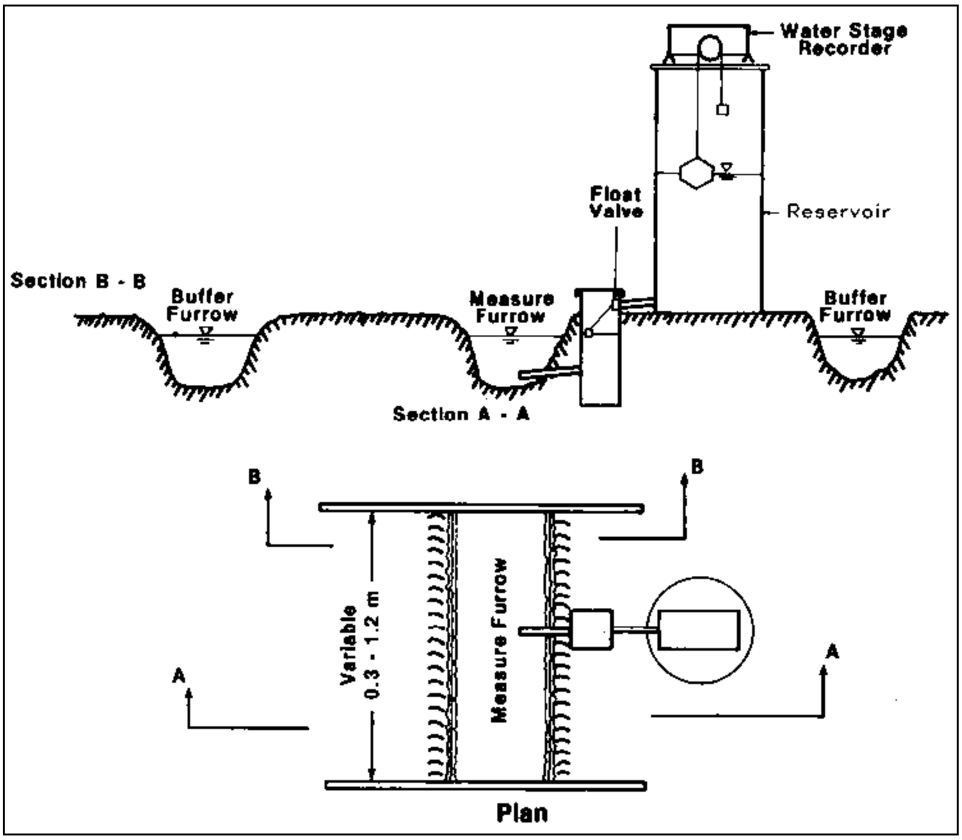


Figure: Pond Methods

c. **Data collection**:

Table: data sheet for measurement of infiltration rate.

Reading on the clock hr./min./sec.	Time difference min.	Cumulative time min.	Water level reading		Infiltration mm.	Infiltration rate mm/min	Infiltration rate mm/hour	Cumulative infiltration mm
			Before Filling mm.	After Filling mm.				

	Start =0	**Start = 0**			**----**	**----**	**----**	**Start = 0**

Column 1 indicates the readings on the clock in hours, minutes and seconds.

Column 2 indicates the difference in time (in minutes) between two readings.

Column 3 indicates the cumulative time (in minutes); this is the time (in minutes) since the test started.

Column 4 indicates the water level readings (in mm) on the measuring rod: before and after filling (see step 5).

Column 5 indicates the infiltration (in mm) between two readings; this is the difference in the measured water levels between two readings. How the infiltration is calculated is indicated in brackets.

Column 6 indicates the infiltration rate (in mm/minute); this is the infiltration (in mm; column 5) divided by the difference in time (in minutes, column 2).

Column 7 indicates the infiltration rate (in mm/hour); this is the infiltration rate (in mm/minute, column 6) multiplied by 60 (60 minutes in 1 hour).

Column 8 indicates the cumulative infiltration (in mm); this is the infiltration (in mm) since the test started. How the cumulative infiltration is calculated is indicated in brackets.

25. **DRAWING OF INFILTRATION CURVE:**

Site location: Example Soil type: Loam Time date………………..

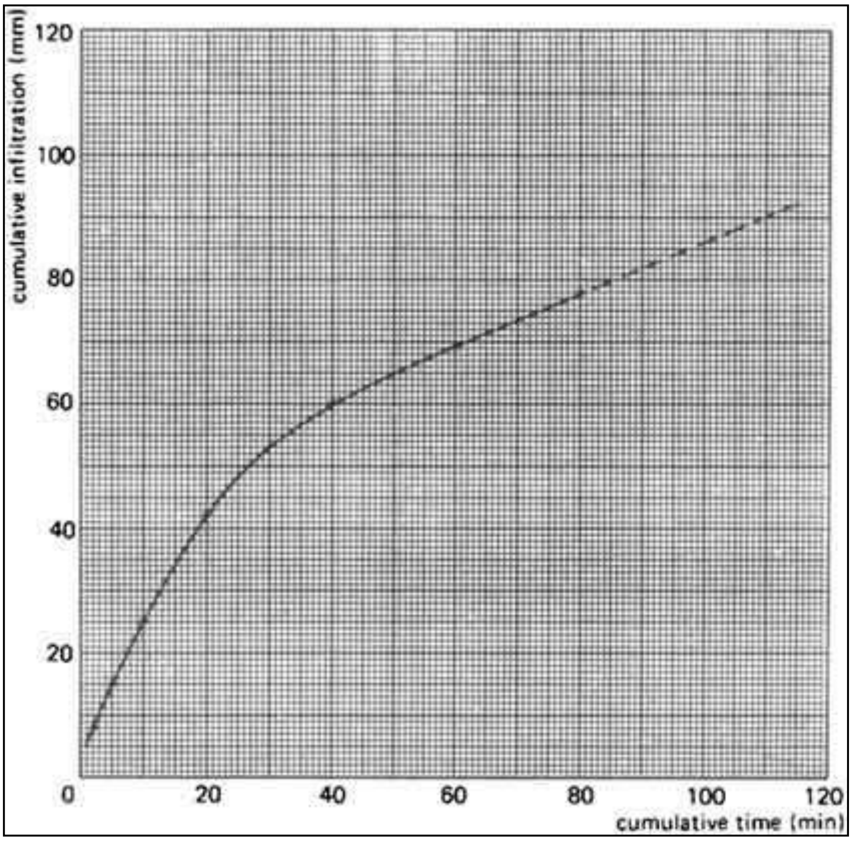
Reading on the clock hr. min. sec.	Time difference min.	Cumulative time min.	Water level reading		Infiltration mm.	Infiltration rate mm/min	Infiltration rate mm/hour	Cumulative infiltration mm
			Before Filling mm.	After Filling mm.				
14 05 00	Start =0	Start = 0		100	----	----	----	Start = 0
	2				(100-92) 8	(8/2) = 4.0	240	
14 07 00		2	92	100				8
	3				(100-93) 7	(7/3) = 2.3	140	
14 10 00		5	93	99				15
	5				(99-89) 10	(10/5) = 2.0	120	
14 15 00		10	89	101				25
	10				(101-84) 17	(17/10) = 1.7	102	
14 25 00		20	84	100				42
	10				(100-89) 11	(11/10) = 1.1	66	
14 35 00		30	89	102				53
	10				(102-95) 7	(7/10) = 0.7	42	
14 45 00		40	95	101				60
	20				(101-92) 9	(9/20) = 0.45	27	
15 05 00		60	92	100				69
	20				(100-91) 9	(9/20) = 0.45	27	
15 25 00		80	91					78

Interpretation:

The basic infiltration rate can be determined from above Table. Column 7: the infiltration rate in am/hour. Once the values of the Infiltration rate are constant, the basic infiltration rate has been reached. In this example the basic infiltration rate is 27 mm/hour and was reached after 60 minutes. After 60 minutes the cumulative infiltration was 69 mm. After the first 60 minutes the infiltration rate is constant: 27 mm/hour. So after 120 minutes (2 hours) the cumulative infiltration will be 69 + 27 = 96 mm (indicated on the graph with a dotted line).

After 3 hours the cumulative Infiltration will be (96 + 27 =) 123 mm, etc. Once the curve has been established it is possible to determine how long it will take to infiltrate a certain amount of water. This is of course important to know when determining the irrigation time.

INFILTRATION CURVE



In the above Figure, the cumulative time (in minutes) is set out against the cumulative infiltration (in mm) and a curve is formed. it can, for be observed that for the example soil type takes 80 minutes to infiltrate approximately 78 mm of irrigation water.

3. Evaporation estimation: Use of evaporation pan and empirical equations using climatic data.

1. Evaporation:

Evaporation is the process in which a liquid changes to the gaseous state as the free surface, below its boiling point, through the transfer of energy.

Evaporation is a cooling process- the latent heat of vaporization (~585 cal/g of evaporated water) must be provided by the water body.

Rate of evaporation depends on- Vapour pressures at the water surface and the air above

Wind speed – Incident solar radiation

Atmospheric pressure – Quality of water

Air and water temperatures

Size of the water body

Vapour pressure – Rate of evaporation is proportional to the difference between the saturation vapour pressure (SVP) at the water temperature and the actual vapour pressure in the air

$$\begin{aligned} &E_L = C\left(e_w - e_a\right) \\ &E_L = rate\ of\ evaporation\ (mm/day) \\ &C = cons\tan t \\ &e_w\ and\ e_a\ are\ in\ mm\ of\ mercury \end{aligned}$$

This equation is called Dalton’s Law of Evaporation

Temperature – Rate of evaporation increases with an increase in water temperature. Although there is an increase in the rate of evaporation with increase in air temperature, a high correlation does not exist between. For the same mean monthly temperature, evaporation from a lake may be different in different months.

Wind – Wind helps to remove the evaporated water vapour from the zone of evaporation, thereby creating greater scope for evaporation.

Rate of evaporation increases with increase in wind velocity up to some limit (critical wind speed) and thereafter any further increase in wind velocity does not have any effect on the evaporation rates. This critical wind speed value is a function of the size of the water surface (large water bodies – high wind speeds)

Atmospheric Pressure – Other factors remaining the same, a decrease in atmospheric pressure (as in high altitude areas) increases t evaporation rate.

Soluble salts – When a solute is dissolved in water, the vapour pressure of the solution is less than that of pure water and hence it causes reduction in the rate of evaporation. The percentage reduction in the evaporation rate approximately corresponds to the percentage increase in specific gravity. Under identical conditions evaporation from sea water is about 2-3% less than that from fresh water

1.1. Estimation / Measurement of Evaporation

This is done by the following methods. Using evaporimeters, using empirical equation.

Types of Evaporators:

Evaporimeter:

These are pans containing water which are exposed to the atmosphere. Loss of water by evaporation from these pans are measured a regular intervals (daily). Meteorological data such as humidity, wind velocity, air and water temperatures, and precipitation are also measured and noted along with evaporation.

An **evaporation pan** is used to hold water during observations for the determination of the quantity of evaporation at a given location. Such pans are of varying sizes and shapes, the most commonly used being circular or square. The best known of the pans are the "Class A" evaporation pan and the "Sunken Colorado Pan". In Europe, India and South Africa, a Symon's Pan (or sometimes Symon's Tank) is used. Often the evaporation pans are automated with water level sensors and a small weather station is located nearby.

Procedures:

1. USWB Class A Evaporation Pan:

A pan of diameter 1210mm and depth 255mm. Depth of water is maintained between 18 and 20cm. The pan is made of unpainted GI sheet. The pan is placed on a wooden platform of height 15cm above ground level to allow free air circulation below the pan. Evaporation is measured by measuring the depth of water in a stilling well with a hook gauge.

2. ISI Standard Pan:

Specified by IS: 5973 and known as the modified Class a Pan. A pan of diameter 1220 mm and depth is 255 mm. The pan is made of copper sheet 0.9mm thick, tinned inside and painted white outside. The pan is placed on a square wooden platform of width 1225mm and height 100mm above ground level to allow free air circulation below the pan. A fixed point gauge indicates the level of water. Water is added to or removed from the pan to maintain the water level at a fixed mark using a calibrated cylindrical measure. The top of the pan is covered with a hexagonal wire net of GI to protect water in the pan from birds. Presence of the wire mesh makes the temperature of water more uniform during the day and night. Evaporation from this pan is about 14% lower as compared to that from an unscreened pan.

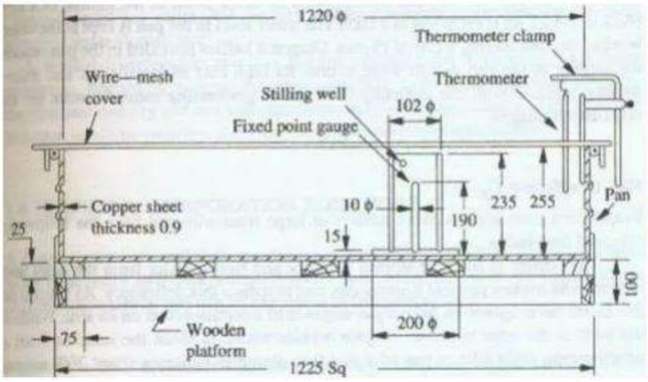


Figure: ISI Evaporation Pan

3. **Colorado Sunken Pan:**

920mm square pan made of unpainted GI sheet, 460mm deep, and buried into the ground within 100mm of the top. Main advantage of this pan is its aerodynamic and radiation characteristics are similar to that of a lake. Disadvantages are difficult to detect leaks, expensive to install, extra care is needed to keep the surrounding area free from tall grass, dust etc.

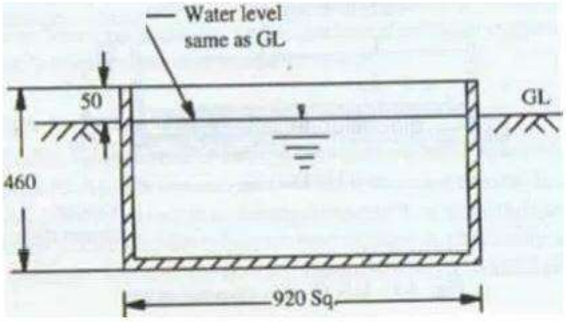


Figure: Colorado Sunken Pan

4. **USGS Floating Pan**:

A square pan of 900 mm sides and 450 mm deep. Supported by drum oats in the middle of a raft of size 4.25m x 4.87m, it is set afloat in a lake with a view to simulate the characteristics of a large body of water. Water level in the pan is maintained at the same level as that in the lake; leaving a rim of 75mm. Diagonal bases are provided in the pan to reduce surging in the pan due to wave action. Disadvantages – High cost of installation and maintenance, difficulty in making measurements.

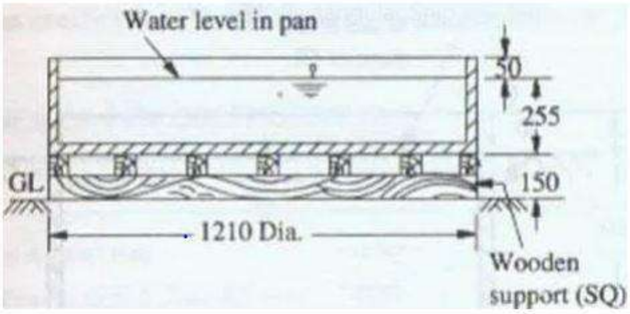


Figure: USGS Class A Evaporation Pan

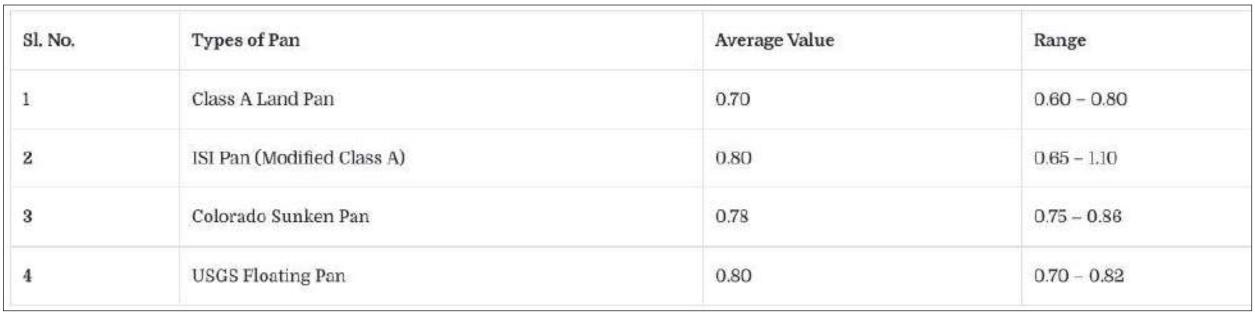
Pan Coefficient:

Evaporation pans are not exact models of large reservoirs. Their major drawbacks are the following:

They differ from reservoirs in the heat storage capacity and heat transfer characteristics from the sides and the bottom (sunken a floating pans aim to minimize this problem). Hence evaporation from a pan depends to some extent on its size (Evaporation from a p of about 3m diameter is almost the same as that from a large lake whereas that from a pan of about 1m diameter is about 20% in excess of this). The height of the rim in an evaporation pan affects wind action over the water surface in the pan. Also it casts a shadow of varying size on the water surface. The heat transfer characteristics of the pan material are different from that of a reservoir. Hence evaporation measured from a pan has to be corrected to get the evaporation from a large lake under identical climatic and exposure conditions.

Lake Evaporation = Pan Coefficient x Pan Evaporation

Table: **Values of Pan Coefficients**



Sl. No.	Types of Pan	Average Value	Range
1	Class A Land Pan	0.70	0.60 – 0.80
2	ISI Pan (Modified Class A)	0.80	0.65 – 1.10
3	Colorado Sunken Pan	0.78	0.75 – 0.86
4	USGS Floating Pan	0.80	0.70 – 0.82

Evaporation pans are normally located at stations where other hydro-meteorological data are collected.

1.3 Empirical equations:

Most of the available empirical equations for estimating lake evaporation are a Dalton type equation of the general form

$$E_L = K\, f(u)(e_w - e_a)$$

E_L = lake evaporation (mm / day)

e_w = saturation vapour pressure at the water surface temperature (mm of merucry)

e_a = actual vapour pressure of the overlying air at a specified height (mm of merucry)

$f(u)$ = wind speed correction function

K = coefficient

e_a is measured at the same height at which wind speed (u) is measured

(1) Meyer's Formula

$$E_L = K_M\,(e_w - e_a)\left[1 + \frac{u_9}{16}\right]$$

E_L = lake evaporation (mm / day)

e_w = saturation vapour pressure at the water surface temperature (mm of merucry)

e_a = actual vapour pressure of the overlying air at a specified height (mm of merucry)

u_9 = monthly mean wind velocity (kmph) at a height of 9m above the ground

K_M = coefficient accounting for other factors (0.36 for large deep waters and 0.50 for small shallow lakes)

(2) Rohwer's Formula

Accounts for the effect of pressure in addition to the wind speed effect

$$E_L = 0.771(1.465 - 0.000732\,p_a)(0.44 + 0.0733\,u_0)(e_w - e_a)$$

p_a = mean barometric pressure (mm of mercury)

u_0 = mean wind velocity in kmph at ground level (taken as the wind velocity at 0.6m height above the ground)

E_L, e_w, and e_a are as mentioned earlier

4. Runoff and discharge estimation: curve number methods for estimating runoff: area-velocity method for discharge estimate

Area velocity method:

The velocity–area method for the determination of discharge in open channels consists of measurements of stream velocity, depth of flow and distance across the channel between observation verticals. The velocity is measured at one or more points in each vertical by current meter and an average velocity determined in each vertical. The discharge is derived from the sum of the product of mean velocity, depth and width between verticals. The discharge so obtained is normally used to establish a relation between water level (stage) and stream flow. Once established, this stage-discharge relation is used to derive discharge values from records of stage at the gauging station

Procedure:

Step 1

Discharge, or the volume of water flowing in a stream over a set interval of time, can be determined with the equation:

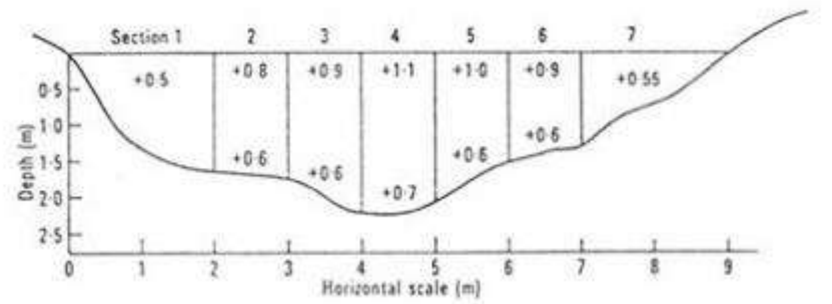
$Q=AV$,
where Q is discharge (volume/unit time-e.g. m^3/second, also called cumecs), A is the cross-sectional area of the stream (e.g. m^2), and V is the average velocity (e.g. m/s).

Step 2

Stream water velocity is typically measured using a current meter. If a current meter is not available, another technique known as the float method can be used to measure velocity. While less accurate, this method requires limited and easy to obtain equipment. To measure velocity via the float method, one simply measures the time it takes for a floating object (such as an orange peel) to travel a measured distance. Velocity is then calculated by dividing the distance traveled by the time it takes for it to travel that distance.

Step 3

Discharge is measured by integrating the area and velocity of each point across the stream; that is, the stream is divided into sections based on where velocity and stage height measurements were taken in the cross-section of the stream. By multiplying the cross-sectional area (width of section x stage height) by the velocity, one can calculate the discharge for that section of stream. The discharge from each section can be added to determine the total discharge of water from the stream.



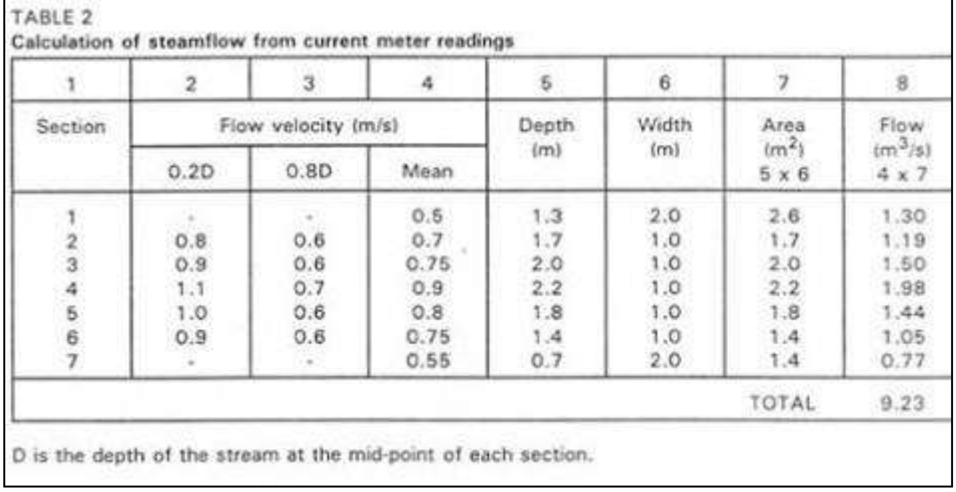


TABLE 2
Calculation of steamflow from current meter readings

1	2	3	4	5	6	7	8
Section	Flow velocity (m/s)			Depth (m)	Width (m)	Area (m²) 5 x 6	Flow (m³/s) 4 x 7
	0.2D	0.8D	Mean				
1	-	-	0.5	1.3	2.0	2.6	1.30
2	0.8	0.6	0.7	1.7	1.0	1.7	1.19
3	0.9	0.6	0.75	2.0	1.0	2.0	1.50
4	1.1	0.7	0.9	2.2	1.0	2.2	1.98
5	1.0	0.6	0.8	1.8	1.0	1.8	1.44
6	0.9	0.6	0.75	1.4	1.0	1.4	1.05
7	-	-	0.55	0.7	2.0	1.4	0.77
						TOTAL	9.23

D is the depth of the stream at the mid-point of each section.

Results Analysis

Discharge measurements using the velocity-area method without the use of a weir provide a good estimate for stream flow and discharge. However, this method assumes several things, including a constant cross-sectional area (which is not always the case, as streams are erosive, dynamic systems), a strong relationship between stage height and discharge, and little human error in measuring velocity, stage height, and cross-sectional area. A weir provides a more reliable measurement due to consistency in channel cross-sectional area and depth, but equations associated with weir discharge measurements were empirically derived, and thus may also have error associated with them due to variability among stream systems. In any case, the greater the number of measurements to derive a ratings curve, the better since a greater range in measurements will be provided. Furthermore, keep in mind that ratings curve measurements may fit a number of lines/equations, depending on environmental factors such as times of snowmelt, where discharge may increase rapidly or times of drought when discharge may be immeasurable via this technique.

5. Construction of hydrograph, unit hydrograph and rating curves

Hydrograph

The graph of flow (rate versus time) at a stream section is called a hydrograph, of which no two are exactly alike. Computation methods for computing peak rates of flow are based upon empirical relations, starting with the Rational Method for peak discharge in the 19th century, progressing to the unit hydrograph in the 1930s, and then to more recent use of dimensionless or index hydrographs. The empirical relations are simple elements from which a hydrograph may be made as complex as needed. Difficulties with hydrograph development lie in the precise estimation of runoff from rainfall and determination of flow paths.

Types of hydrographs

This classification of hydrographs is a partial list, suitable for use in watershed work.

- Natural hydrograph—obtained directly from the flow records of a gagged stream
- Synthetic hydrograph—obtained by using watershed parameters and storm characteristics to simulate a natural hydrograph
- Unit hydrograph—a discharge hydrograph resulting from 1 inch of direct runoff distributed uniformly over the watershed resulting from a rainfall of a specified duration

Procedure:

Unit-hydrograph:

General:

In order to construct unit hydrograph for any drainage basin it is necessary to collect concurrent basic rainfall and discharge data. The rainfall data should be obtained from well distributed rain gauging stations equipped with self recording rain gauges which give areal and time distribution of rainfall. Also continuous stage hydrograph or discharge hydrograph data from water level recorder which gives complete shape of hydrograph at the outlet of the drainage basin is required.

The collected rainfall data is analyzed to obtain hyetograph of effective rainfall of specific or unit duration. Similarly corresponding direct runoff hydrograph is obtained from the total discharge hydrograph. These two things form the two basic requisites in derivation of unit hydrograph.

The construction of unit hydrograph can be accomplished in the following steps:

1. From the past rainfall records select an isolated intense storm-rainfall of specific or unit duration.

2. For this storm using isohyetal or Thiessen polygon method calculate average depth of precipitation over the drainage basin.

3. Using (SRRG) self recording rain gauge data of all the available stations plot mass curves of rainfall for this storm and obtain, average mass curve of rainfall.

4. From the average mass curve of rainfall construct hyetograph. To construct hyetograph incremental rainfall quantities during successive units of time are obtained from the mass curve. The average depths of rainfall per unit of time are then plotted on ordinate against time as abscissa.

5. Using stage hydrograph and stage-discharge relationship obtain a complete discharge hydrograph (covering some time before as well as after the storm) at the drainage outlet for the selected storm.

6. If the recession limb is not smooth and contains bumps, make recession limb smooth or normal by removing the bumps.

7. Separate the base flow from total storm hydrograph using suitable empirical method.

8. Subtracting the base flow components plot and obtain ordinates of direct runoff hydrograph.

9. Either by planimeter or by mathematical calculations find out the volume .of the direct runoff.

10. Convert this volume into cm of runoff over the catchment area. For example:

Volume of direct runoff = Area within the hydrograph = $\sum$ Ordinates x t = $\sum 0$ x t

Where $\sum$ Ordinates = Sum of the ordinates of direct runoff hydrograph at equal time interval

t = Time interval between successive ordinates

To get volume of runoff in m^3, ordinates have to be converted in cusec and time interval in seconds.
This volume can be converted into cm of runoff by dividing the same by the area of the drainage basin m^2 x 100.
Depth of direct runoff = Effective rainfall

11. The duration of effective rainfall of the storm of specific or unit duration is determined by drawing a horizontal line on the hyetograph in such a way that the area of the hyetograph above the horizontal line is equal to the volume of direct runoff. Obviously the area below the horizontal line gives the abstractions. This is an arbitrary method. For elaborate analysis infiltration indexes and curves will have to be used.

12. Measure the ordinates of direct runoff hydrograph.

13. Divide these ordinates of direct runoff hydrograph by the obtained depth of runoff in cm to get ordinate of unit hydrograph.

Mathematically,

Ordinate of direct runoff hydrograph = Ordinate of direct runoff hydrograph/Depth of direct runoff in cm

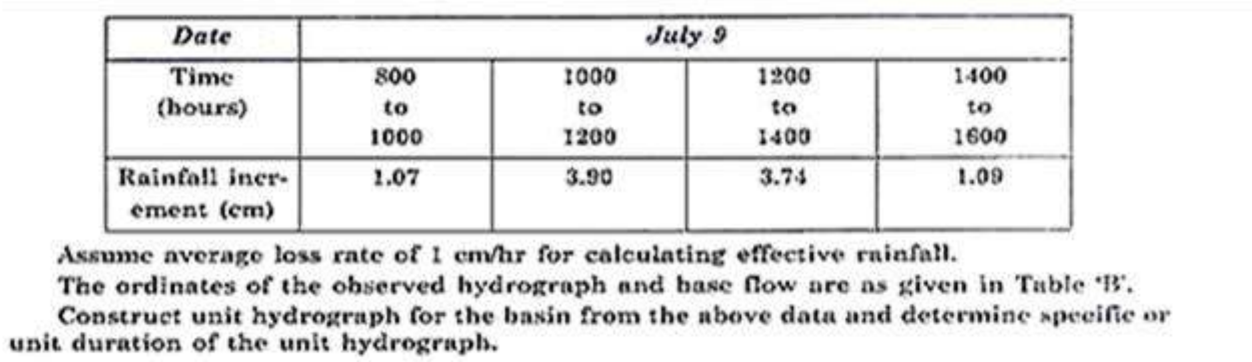
14. Plot these ordinates against uniform and the same time interval as the one used in direct runoff hydrograph to get unit hydrograph.

Derivation of unit hydrograph can be done very conveniently by making step-by-step calculations in a tabular form. Following example makes the procedure clear.

Problem:
On a drainage basin of 400 km^2 size 8 hours storm was selected for construction of unit hydrograph.

The rainfall increments observed from the average mass curve of the storm rainfall are as given in Table 'A' below:

Table A

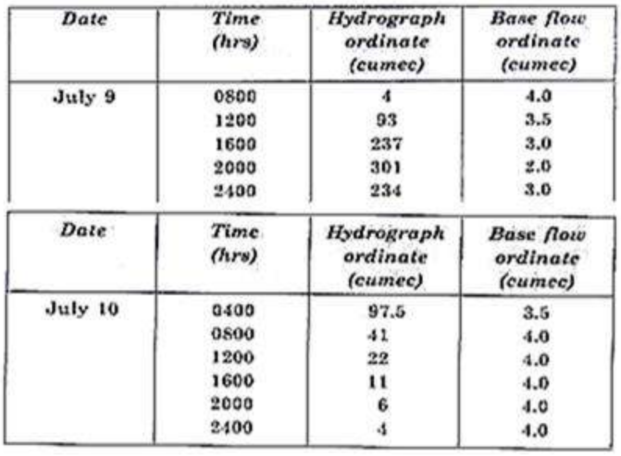


Date	July 9			
Time (hours)	800 to 1000	1000 to 1200	1200 to 1400	1400 to 1600
Rainfall increment (cm)	1.07	3.90	3.74	1.09

Assume average loss rate of 1 cm/hr for calculating effective rainfall.

The ordinates of the observed hydrograph and base flow are as given in Table 'B'.

Construct unit hydrograph for the basin from the above data and determine specific or unit duration of the unit hydrograph.



Date	Time (hrs)	Hydrograph ordinate (cumec)	Base flow ordinate (cumec)
July 9	0800	4	4.0
	1200	93	3.5
	1600	237	3.0
	2000	301	2.0
	2400	234	3.0
July 10	0400	97.5	3.5
	0800	41	4.0
	1200	22	4.0
	1600	11	4.0
	2000	6	4.0
	2400	4	4.0

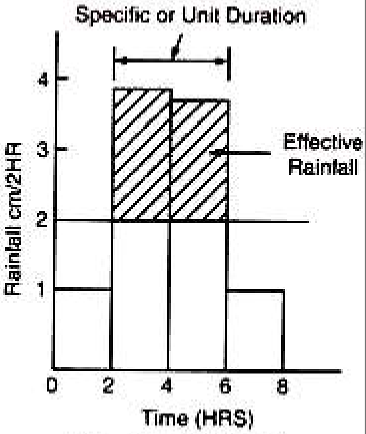


Fig. 4.8. Problem 1
Hyetograph

Solution

Step 1:

Using rainfall data hyetograph can be constructed as shown in Figure. The horizontal line (ϕ line) can be drawn at 2 cm ordinate. The area above the line gives effective rainfall. It may be also seen that the duration of effective rainfall is 4 hours which is equal to specific or unit duration of the hydrograph.

Step 2:

The amount of effective rainfall can be calculated as shown in Table 4.5. The total effective rainfall works out to be 3.64 cm.

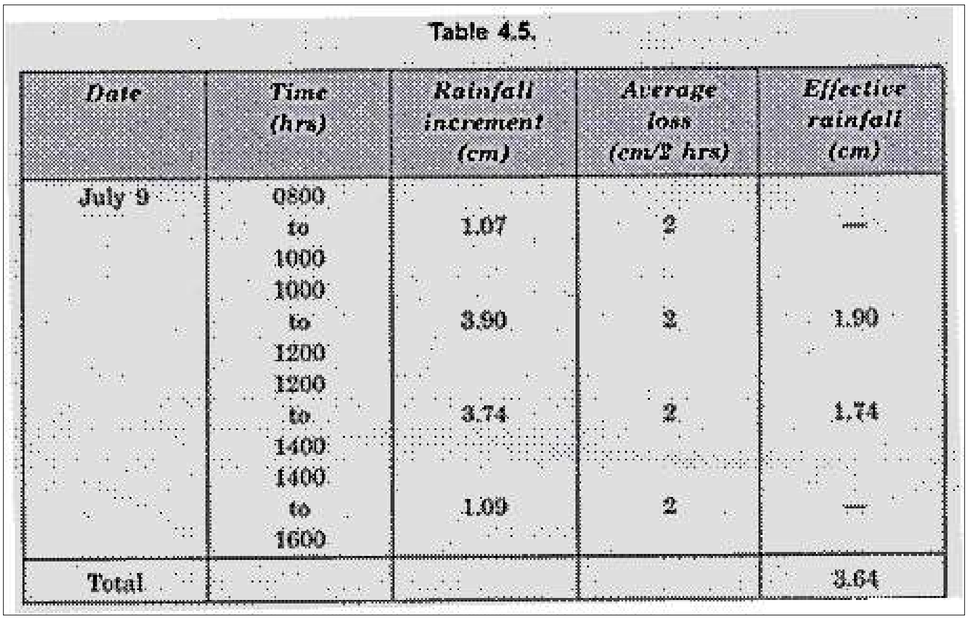


Table 4.5.

Date	Time (hrs)	Rainfall increment (cm)	Average loss (cm/2 hrs)	Effective rainfall (cm)
July 9	0800 to 1000	1.07	2	—
	1000 to 1200	3.90	2	1.90
	1200 to 1400	3.74	2	1.74
	1400 to 1600	1.09	2	—
Total				3.64

Step 3:

The ordinates of the direct runoff hydrograph and 4 hour unit hydrograph can be calculated as shown in Table 4.6. It may be noted that

Direct runoff ordinate = Total runoff ordinate – Base flow ordinate, and

Unit hydrograph ordinate = Direct runoff ordinate/Direct runoff expressed in cm

Step 4:
Volume of direct runoff = ∑0 x t = 1011 x 4 x 60 x 60 = 4044 x 3600 m^3

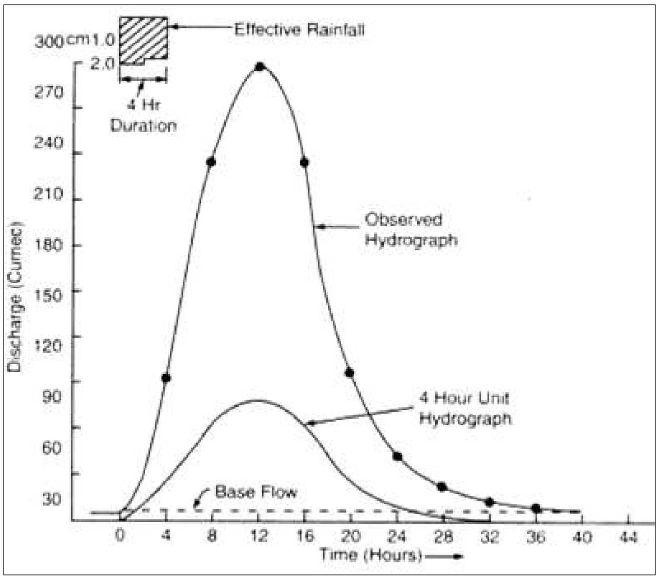
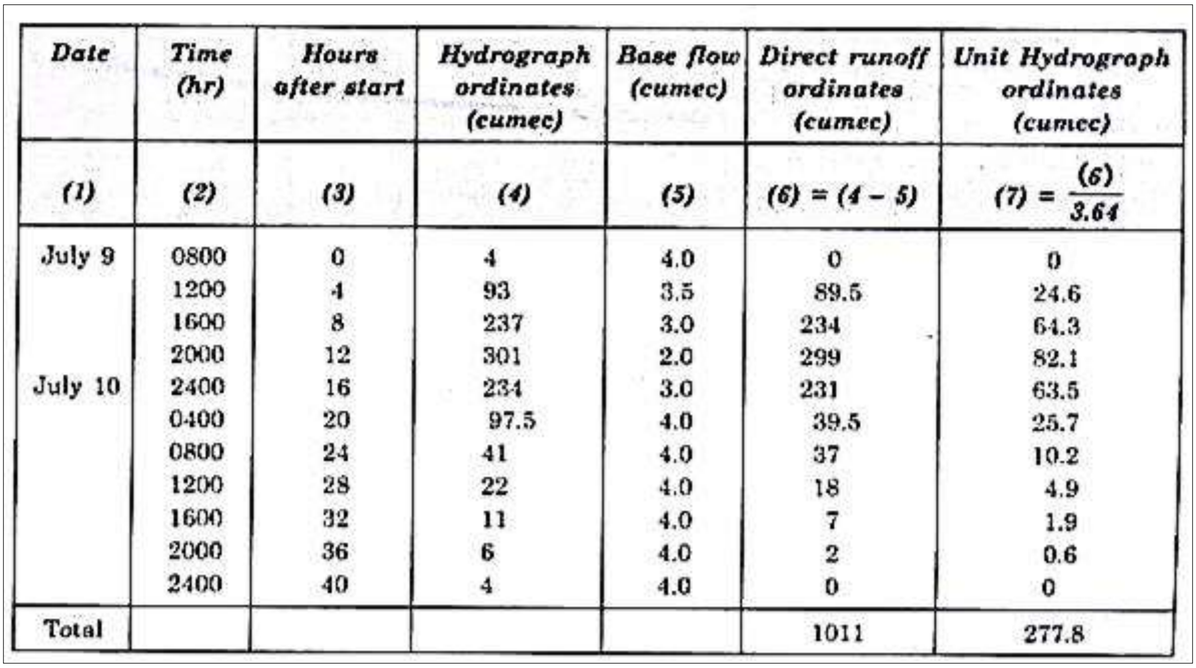


Figure: Problem Unit hydrograph construction

Step 5:

Depth of direct runoff in c = [(4044 X 3600) / Area of basin in m^2] X 100
= (4044 X 3600X100) / (400 X 1000 X 1000) = 3.64 cm



Date	*Time (hr)*	*Hours after start*	*Hydrograph ordinates (cumec)*	*Base flow (cumec)*	*Direct runoff ordinates (cumec)*	*Unit Hydrograph ordinates (cumec)*
(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6) = (4 – 5)*	$(7) = \frac{(6)}{3.64}$
July 9	0800	0	4	4.0	0	0
	1200	4	93	3.5	89.5	24.6
	1600	8	237	3.0	234	64.3
	2000	12	301	2.0	299	82.1
July 10	2400	16	234	3.0	231	63.5
	0400	20	97.5	4.0	39.5	25.7
	0800	24	41	4.0	37	10.2
	1200	28	22	4.0	18	4.9
	1600	32	11	4.0	7	1.9
	2000	36	6	4.0	2	0.6
	2400	40	4	4.0	0	0
Total					1011	277.8

From step 2 and step 5
Depth of direct runoff =Depth of effective rainfall = 3.64 cm

Hence, stepwise calculations are correct.

Step 6:

Volume of runoff from unit hydrograph = ∑ 0 x t = 277.8 x 4 x 60 x 60 m^3
Depth of runoff from unit hydrograph in cm = 277.8 x 4 x 60 x 60/400 x 1000×1000 x 100 = 1cm

(This is as per definition of unit hydrograph)

Step 7:

Now using the values in columns (3) and (7) ordinates of unit hydrograph can be plotted against time as abscissa to construct unit hydrograph as shown in above Figure.

Rating Curve:

In hydrology, a rating curve is a graph of discharge versus stage for a given point on a stream, usually at gauging stations, where the stream discharge is measured across the stream channel with a flow meter. Numerous measurements of stream discharge are made over a range of stream stages. The rating curve is usually plotted as discharge on x-axis versus stage (surface elevation) on y-axis.

Procedure:

The development of a rating curve involves two steps.

Step 1

In the first step the relationship between stage and discharge is established by measuring the stage and corresponding discharge in the river.

Step 2

Second part, stage of river is measured and discharge is calculated by using the relationship established in the first part. Stage is measured by reading a gauge installed in the river. If the stage-discharge relationship does not change with time, it is called permanent control. If the relationship does change, it is called shifting control. Shifting control is usually due to erosion or deposition of sediment at the stage measurement site. Bedrock-bottomed parts of rivers or concrete/metal weirs or structures are often, though not always, permanent controls.

If G represents stage for discharge Q, then the relationship between G and Q can possibly be approximated with an equation:

$$Q = C_r (G - a)^{\beta}$$

Where C_r and β are rating curve constants, and α is a constant which represents the gauge reading corresponding to zero discharge. The constant can be measured when a stream is flowing under "section control" as the surveyed gauge height of the lowest point of the section control feature. When a stream is flowing under "channel control" conditions, the parameter does not have a physical analogue and must be estimated by following standard methods given in literature. The parameter is typically in the range of 2.0 to 3.0 when a stream is flowing under section control and in the range of 1.0 to 2.0 when a stream is flowing under channel control.

A stream will typically transition from section control at lower gauge heights to channel control at higher gauge heights. The transition from section control to channel control can often be inferred by a change in the slope of a rating curve when plotted on log-log graph paper.

Unit - GEO 195.2: SEDIMENTOLOGICAL ANALYSIS

Sedimentology encompasses the study of modern sediments such as sand, silt, and clay and the processes that result in their formation (erosion and weathering), transport, deposition and diagenesis. Sedimentologists apply their understanding of modern processes to interpret geologic history through observations of sedimentary rocks and sedimentary structures. The identification of various sedimentation processes from their deposits, or sedimentary facies, is crucial to the recognition and palaeogeographic reconstruction of ancient sedimentary environments.

1. Phi-Scale of Grain Size Distribution, Texture Analysis of Sediment Samples Using Standard Techniques, Statistical Representation.

1.1. The phi scale/Phi grade scale

The phi scale is a sediment particle size scale, defined as a logarithmic transformation of the geometric Udden-Wentworth grain size scale (AGI, 2013). The phi diameter is calculated as the negative logarithm to the base 2 of the particle diameter (in millimetres). The phi scale was introduced by Krumbeinas (1934, 1938) a convenient means of visualizing and statistically analyzing sediment grain size distributions over a wide range of particle sizes.

The expression of grain sizes on a logarithmic scale. The phi value (ϕ) is related to grain diameter in mm (d) by the expression $\boldsymbol{\phi = -\log_2 d}$. Increasing positive phi values are for grain diameters progressively finer than 1000 μm, and increasing negative values for grain diameters progressively coarser than 1000 μm (e.g. 2ϕ = 250 μm; 1ϕ = 500 μm; 0ϕ = 1000 μm; -1ϕ = 2 mm; -2ϕ = 4 mm).

Although no single grade scale will best serve all uses for describing texture, the phi scale does have the following advantages as summarized by the Inter-Society Grain Size Committee of the Society of Economic Paleontologists and Mineralogists (from Tanner, 1969):

- Evenly spaced division points, facilitating plotting;
- Geometric basis allowing equally close inspection of all parts of the size spectrum;
- Simplicity of subdivision of classes to any precision desired, with no awkward numbers;
- Wide range of values, extending automatically to any extreme;
- Widespread acceptance;
- Coincidence of major dividing points with natural class boundaries (approximately);
- Ease of use in probability analysis;
- Ease of use in computing statistical parameters;
- Amenability of more advanced analytical methods;
- Fairly close approximation to most other scales, allowing easy adoption; and
- Phi-size screens are available commercially.
- No other grade scale is even close to satisfying this list and few have more than three or four of these advantages.

Box 1. Symbols and Definitions

$\boldsymbol{d}$ (mm) grain diameter expressed in millimetres

$\boldsymbol{M_\phi}$ phi mean of sample grain-size distribution (an estimate of μ)

$\boldsymbol{Md_\phi}$ 50th percentile phi size

$\boldsymbol{S_\phi}$ phi sorting of sample grain-size distribution (an estimate of a)

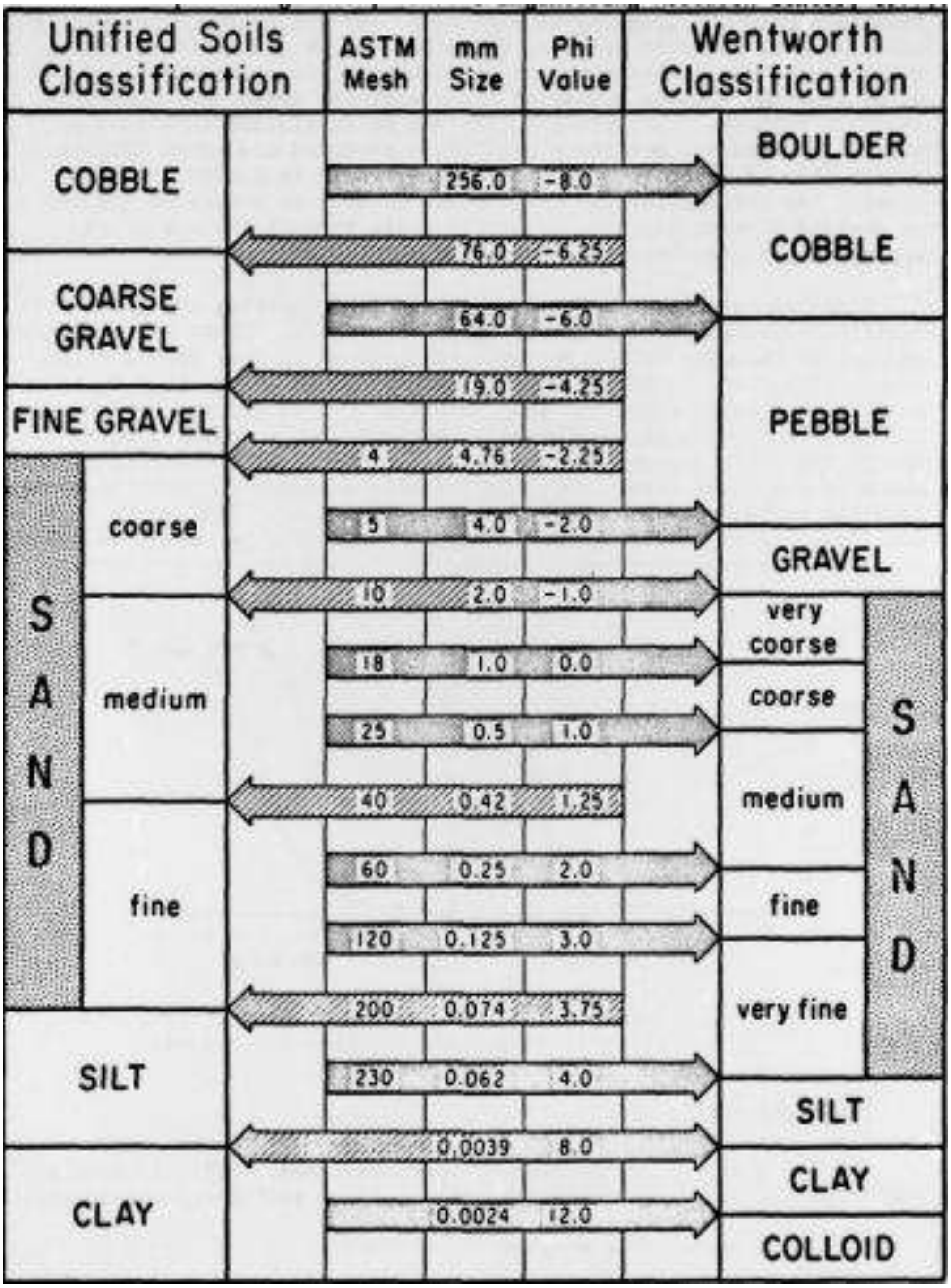
$\boldsymbol{Sk_\phi}$ phi skewness measure of asymmetry for a sample grain-size distribution

$\boldsymbol{\phi}$ a measure of sedimentary particle size

$\boldsymbol{\mu}$ mean of a lognormal distribution

$\boldsymbol{\sigma}$ standard deviation of a lognormal distribution

Table 1: Grain-size scales--soil classification (modified from U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977).



1.2. Texture Analysis of Sediment Samples Using Standard Techniques

Particle size distribution is one of the most stable soil or sediment characteristics, and is a significant controlling factor for such characteristics as:

- Porosity
- Permeability
- Water holding capacity
- Leaching potential

- Exchangeable nutrient supply
- Cation exchange
- Weathering behaviour
- Susceptibility to wind and water transport
- The mechanical and geotechnical behaviour of the soil

Different methods are required for determining grain size in loose (unconsolidated) sediment which includes:

- Gravels and pebbles can be measured using calipers[1].
- Sands and gravel grains can be measured using sieves of different mesh size that are mechanically shaken. The amount trapped in each sieve is weighed and taken as an estimate of the particle size range in the sample.
- Silts and clays are more difficult to measure -- the commonest method is elutriation, where a sample treated with a dispersant is placed in cylinder. The finest fractions stay in suspension longest, whereas the heavier (larger) fractions generally sink more rapidly, but at a predictable rate according to Stokes' Law. Samples are withdrawn at a given depth at specific intervals, then dried and weighed. From these data, it is possible to calculate the particle size ranges semi-quantitatively.
- Direct measurement of clay particles is only possible using an electron microscope.
- Digital image processing can also be applied to particle size measurement (but only in 2D).

Sieve and Pipette Method

For size measurement, a bank of sieve is taken with downward decreasing opening (mesh) size (Fig. 1). Sediment with measured weight is kept on the topmost sieve and then the sieve bank is mechanically or electrically shaken. Depending on the size of grains, the sediment get distributed among the sieves used; grains larger than the sieve size will remain on the sieve and grains with smaller size pass on to the sieves further down. By weighing fraction of sample lying on each sieve, a grain size distribution curve is constructed. The lower limit of sieve analysis is 0.04-0.03 mm, grains finer than this size show large amount of cohesion and do not allow measurement of individual grain by this method.

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[1] A Caliper is a type of measuring tool that measures the distance between two opposite sides of an object. Calipers are meant for measuring thicknesses and internal or external diameters inaccessible to a scale.

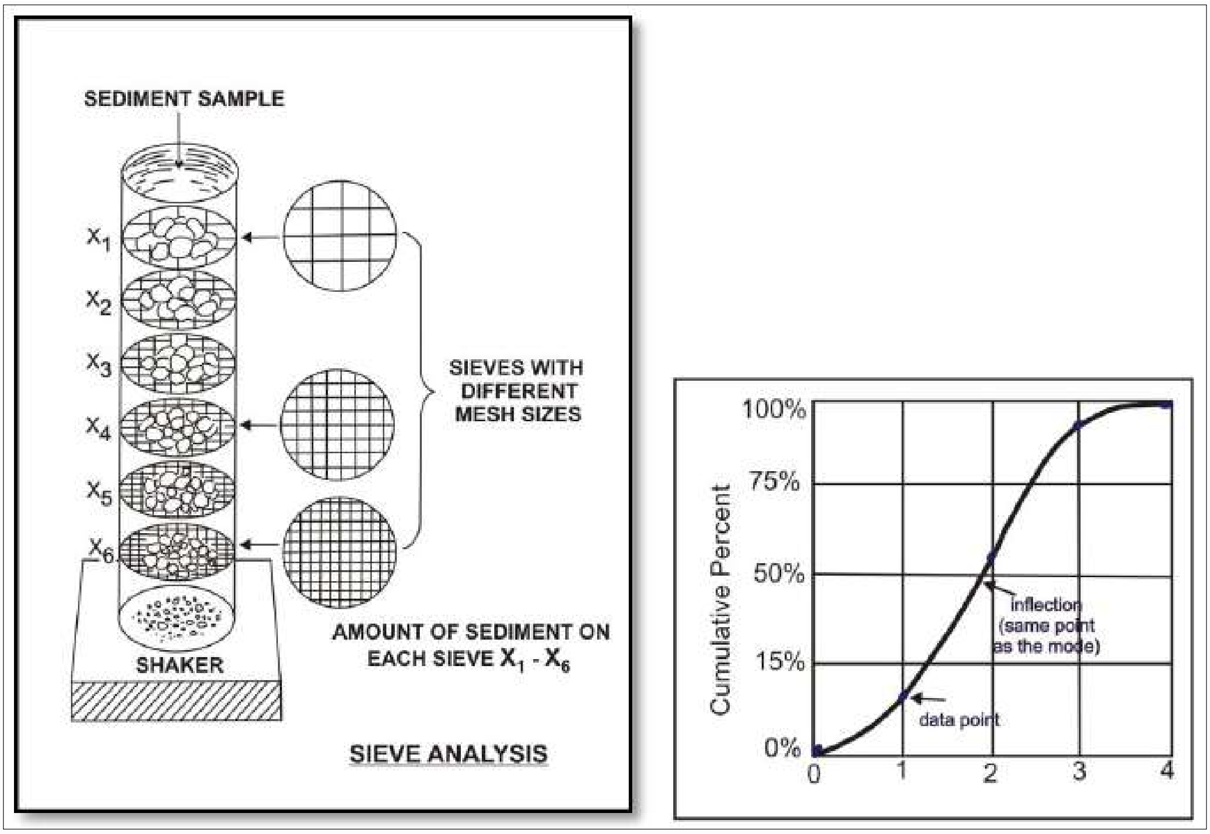


Fig. 1: Bank of sieves with decrease in opening size downward

Sediments (silt and clay) cannot be measured by sieve analysis because of their high cohesive character. In lieu, measurement of size for these sediments are done through number of other methods, most of which deals with settling velocity of sediment grain in liquids following Stoke's law. This is designed to represent particles of specified diameters based on the individual fraction settling rate.

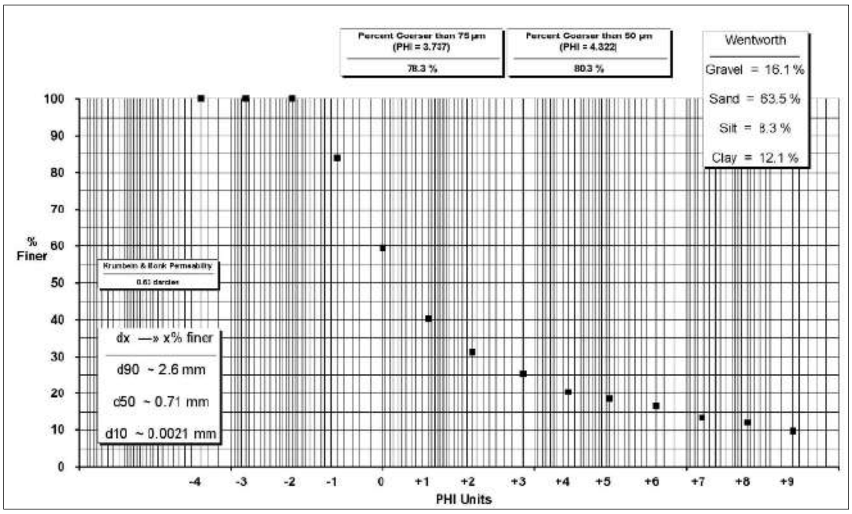


Fig. 2: Particle Size Graph

The sieve and pipette method uses the Wentworth classification system, which breaks down soil structure into the level of gravel, sand, silt, clay and phi. This classification system is most commonly used in North America for particle size and is recommended for environmental soils and sediments.

1.3. Statistical Representation

Grain size analyses may either be plotted directly in millimetres, using a logarithmic base paper; or they may be plotted in phi units (Φ), in which case arithmetic base paper is used. The latter is much more convenient and accurate to read. Grain size distribution curve is a result of interplay of many factors which include:

- Availability of grain sizes in the provenance,
- Sediment transport mechanism i.e. bedload, saltation or suspension, and
- Depositional environment and processes operative therein.

Hence, a careful analysis of grain size distribution curve may offer understanding about each of these factors. Different methods of statistical analyses of grain size data are presented in Table 2.

Table 2: Different Methods of Statistical Representation of Sedimentological Data.

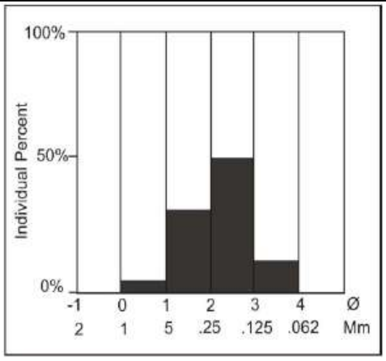
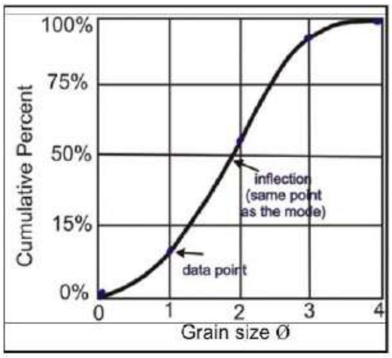
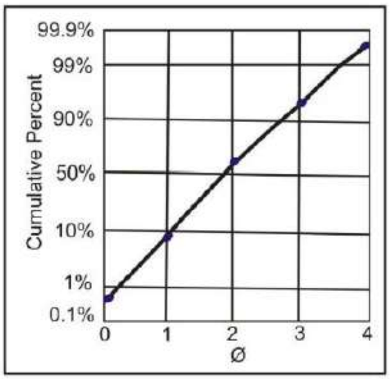
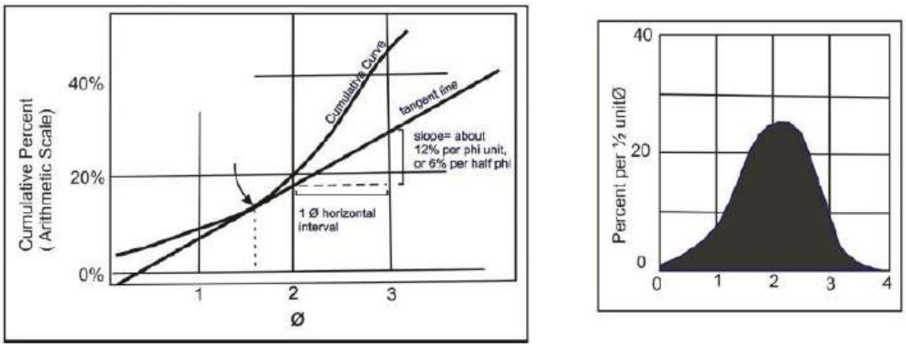
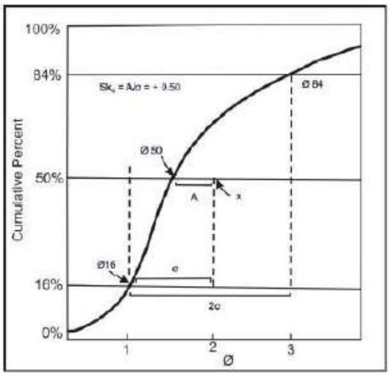
Histogram	 **Fig.3:** Sediments of different size grades plotted as columns in a histogram
Cumulative Curve, Arithmetic Ordinates	

	Fig. 4: A cumulative frequency curve plotted with arithmetic ordinate
Cumulative Curve, Probability Ordinate	 **Fig. 5:** Cumulative curve plotted on probability ordinate. Note that the 'S' shaped curve in arithmetic ordinate has transformed into a straight line curve in probability ordinate
Frequency Curve	 **Fig. 6:** Frequency curve constructed by measurement of slopes on cumulative percent curve
Measures of Average Size	**a. Mode (M_O):** is the most frequently-occurring particle diameter. It is the diameter corresponding to the steepest point (point of inflection) on the cumulative curve (only if the curve has an arithmetic frequency scale). It corresponds to the highest point on the frequency curve. **b. Median (M_d):** Half of the particles by weight are coarser than the median, and half are finer. It is the diameter corresponding to the 50% mark on the cumulative curve and may be expressed either in Φ or mm. (MdΦ or Mdmm).

	c. Graphic Mean (M_Z): The best graphic measure for determining overall size is the Graphic Mean, given by the formula: $M_Z = (\Phi\ I6 + \Phi SO + \Phi\ 84)/3$.
Inclusive Graphic Standard Deviation (σ_{I},)	The Graphic Standard Deviation, σ_G, is a good measure of sorting and is computed as $(\Phi 84-\Phi 16)/2$. However, this takes in only the central two thirds of the curve and a better measure is the inclusive Graphic Standard Deviation, σI, given by the formula $(\Phi\ 84 - \Phi\ 16)/4 + (\Phi 95- \Phi 5)/6.6$ Measurement of sorting values for a large number of sediments has suggested the following verbal classification scale for sorting: σ_I under .35 Φ, very well sorted .35-.50 Φ, well sorted .50-.71Φ, moderately well sorted .7l- l.0 Φ, moderately sorted 1 .0- 2.0 Φ, poorly sorted 2.0-4.0 Φ, very poorly sorted over 4.041, extremely poorly sorted
Measures of Skewness or Asymmetry	 **Fig. 7:** Measure of Asymmetry (Skewness) of Curve

2. Form and Shape Analysis of Pebble Grade Sediments

The shape of sedimentary particles is an important physical attribute that may provide information about the sedimentary history of a deposit or the hydrodynamic behaviour of particles in a transporting medium. It is determined by the following factors:

- Original shapes of mineral grain in the source rocks
- Orientation and Spacing of fractures in bedrock
- Nature and Intensity of sediment transport
- Sediment burial processes
- Measuring Particle Shape

Standardized numerical shape indices have been developed to facilitate shape analyses by mathematical or graphical methods. Quantitative measures of shape can be made on two-dimensional images or projections of particles or on the three-dimensional shape of individual particles. Two-dimensional particle shape measurements are particularly applicable when individual particles cannot be extracted from the rock matrix. Three-dimensional analyses of individual irregularly shaped particles generally involve measuring the principal axes of a triaxial ellipsoid to approximate particle shape (Figure 8).

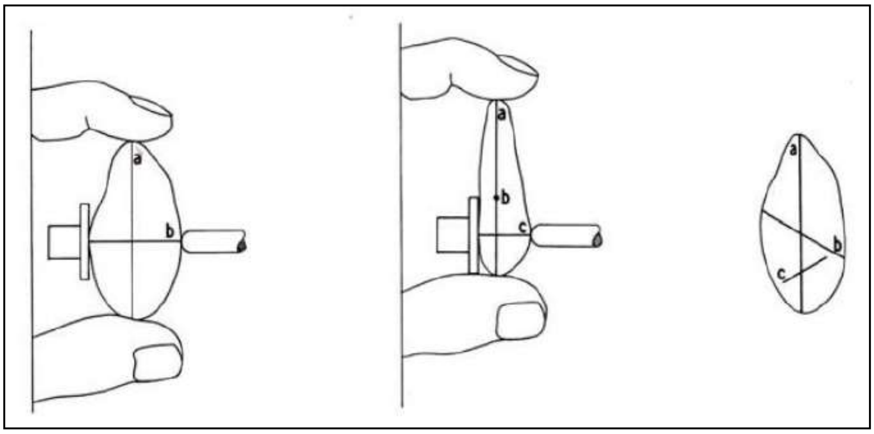


Fig. 8: Concept and Measurement of Pebble Diameter (Krumbein, 1941 and Pettijohn, 1975).

2.1. Roundness

Roundness indices generally compare the outline of the two-dimensional projection of the particle to a circle Wentworth (1919) first defined roundness as:

$$Roundness = \frac{r_i}{R}$$

Where,

r_i is the radius of curvature of the sharpest corner, and

R is the radius of the smallest circumscribing sphere.

The Wadell Roundness (Wadell, 1932) index is given by:

$$Roundness = \frac{\sum_{i=1}^{n}\left(\frac{r_i}{R}\right)}{n}$$

Where,

r_i is the radius of curvature of particle corners, and

R is the radius of the largest inscribed sphere, and

n is the number of particle corners measured.

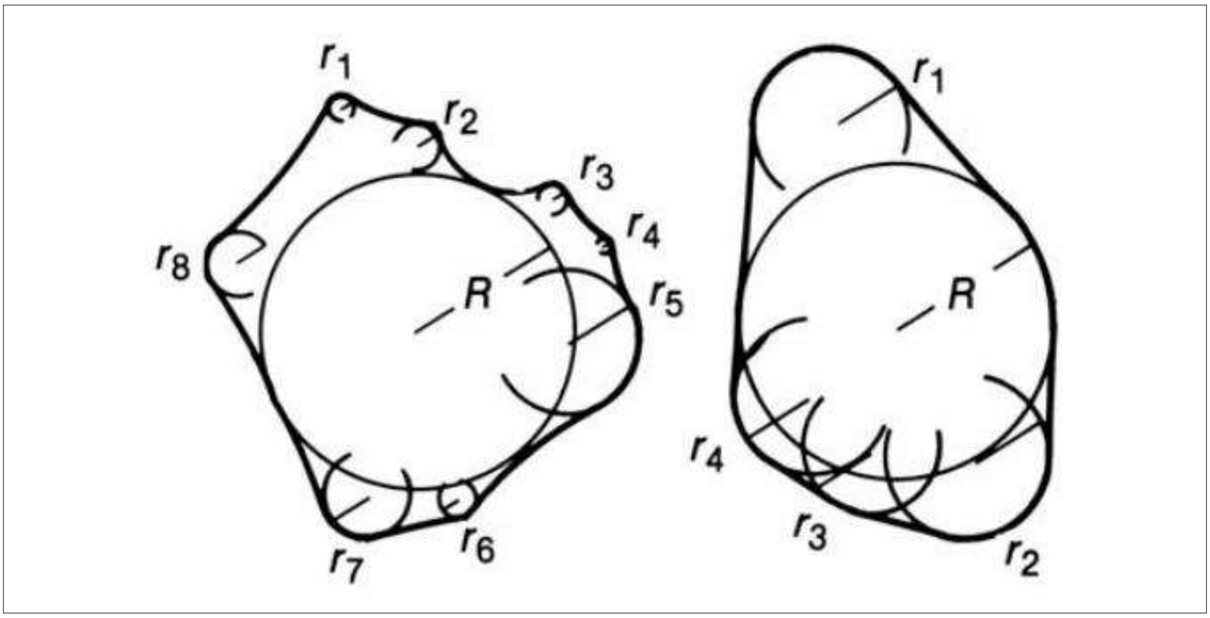


Fig. 9: Two-dimensional particle images showing definitions for the radii of individual corners (r1, r2, and etc.) and the maximum inscribed circle (R) (Krumbein, 1940 in Friedman, et al., 1992).

The measurements are generally taken from two-dimensional images of the maximum projection area of the particle (i.e. the a-b plane).

2.2. Sphericity

Operational Sphericity (Wadell, 1932) is given by:

$$\psi = \left(\frac{V_p}{V_{cs}} \right)^{1/3}$$

Where,

V_p is the particle volume, and V_{cs} is the volume of the smallest circumscribing sphere. This equation may be approximated by:

$$\psi = \frac{abc}{a^3} = \left(\frac{bc}{a^2} \right)^{1/3}$$

Where,

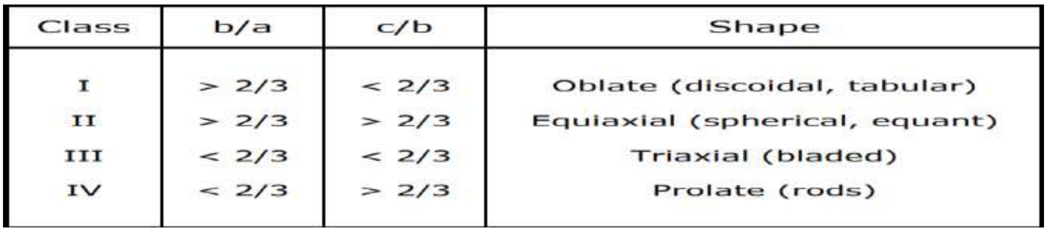
a, ***b***, and ***c*** are the long intermediate and short axis dimensions, respectively, of the particle (Krumbein, 1941).

Sphericity values range from 0 (nonspherical) to 1 (perfect sphere) with most sedimentary particles falling in the range of 0.3 to 0.9.

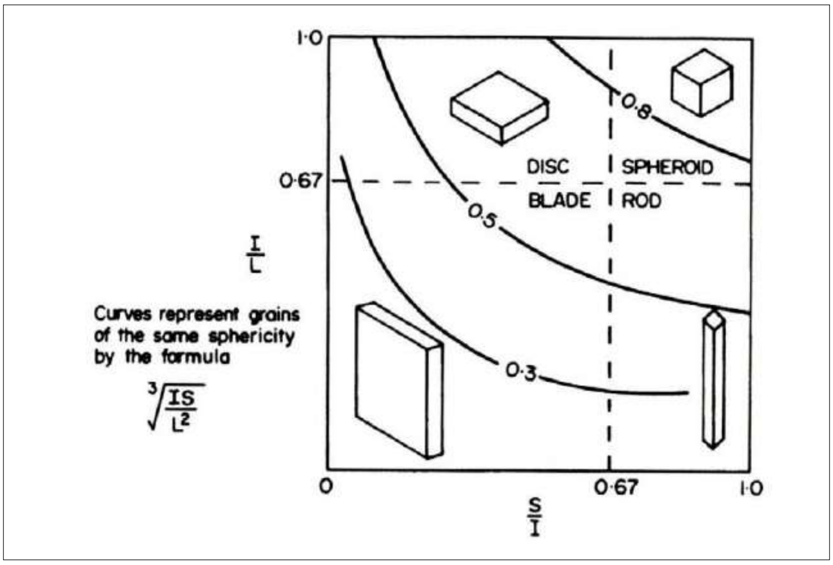
2.3. Zingg Shape Classification

Zingg (1935) classified the particles into four form categories; spheroids, discoids, rods, or blades based upon the b/a and c/b ratios as shown in Table 3. These classes are shown graphically in the Zingg diagram (Figure 10), which includes representative solids of equal roundness (roundness = 0). Lines of equal sphericity, based on the Wadell-Krumbein sphericity index are added to the Zingg diagram.

Table 3: Zingg Shape Classes (after Zingg, 1935 in Pettijohn, 1975).



Class	b/a	c/b	Shape
I	> 2/3	< 2/3	Oblate (discoidal, tabular)
II	> 2/3	> 2/3	Equiaxial (spherical, equant)
III	< 2/3	< 2/3	Triaxial (bladed)
IV	< 2/3	> 2/3	Prolate (rods)



Where,

I=Intermediate,

S=Short, and

L=Long

Fig. 10: Zingg diagram showing lines of equal Wadell sphericity (from Lewis and McConchie, 1994)

2.4. Sneed and Folk Sphericity-Form Diagram

The maximum projection sphericity of a particle is given by the equation (after Sneed and Folk, 1958):

$$\psi_p = \left(\frac{c^2}{ab} \right)^{1/3}$$

The maximum projection sphericity is represented in the sphericity-form diagram of Sneed and Folk (1958) (Figure 11).

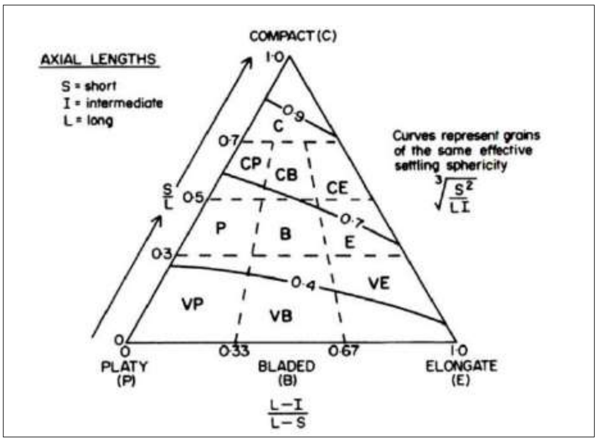


Fig. 11: Sphericity-form diagram of Sneed and Folk (1958) (from Lewis and McConchie, 1994).

2.5. Cailleux Flatness Index

Cailleux (1945) developed the flatness index based upon the relationship between the particle dimensions along the three principal axes. The index is given by:

$$F = \left(\frac{a+b}{2c} \right)$$

The index ranges from a minimum value of 1 for an equant particle and becomes progressively larger the flatter the particle. There is no maximum limit.

2.6. Power's Scale of Roundness

Powers (1953) developed visual comparison chart of reference particles of known sphericity and roundness (Figure 12).

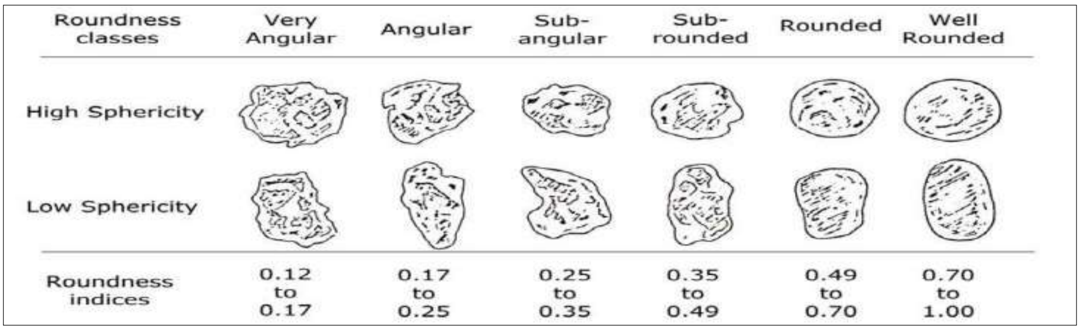


Fig. 12: Chart for estimating the roundness and sphericity of sedimentary particles based upon comparisons with particles of known sphericity and roundness (based on Powers, 1953).

The roundness classes are based upon another Wadell roundness index given by:

$$\rho = \frac{r}{R}$$

Where,

r is the radius of curvature of the largest inscribed circle, and

R is the radius of the smallest circumscribing circle.

The index ranges from 0 to 1, with 1 indicating a perfect circle. The class between 0.00 and 0.12 is excluded, because natural particles generally have roundness values greater than 0.12.

3. Megascopic and Microscopic Examination of Sediments

3.1. Megascopic Examination of Sediments

Approximately 75% of the Earth's surface is covered by sedimentary rocks. This course will help students learn to identify and characterize both clastic and chemical sedimentary rocks at macro- and microscopic scales. Besides, students will be introduced to the study of sedimentary textures, structures, and paleocurrent and facies analyses as tools for environmental reconstructions.

On the basis of physical characters or megascopic properties, sedimentary rock samples are examined and identified in the field and laboratory with unaided eyes. In this experiment, you will study the megascopic characters of some important clastic rocks such as conglomerate, breccia, sandstone, siltstone, shale, and non-clastic rocks such as limestone, fossiliferous limestone, oolitic limestone and chert.

Requirements

Hand specimens of the clastic rocks such as conglomerate, breccia, sandstone, siltstone, shale, and non-clastic rocks such as limestone, fossiliferous limestone, oolitic limestone and chert.

- Hand lens
- Laboratory file, scale, pen/ pencil and eraser
- Dilute hydrochloric acid (HCl)

Laboratory Exercises

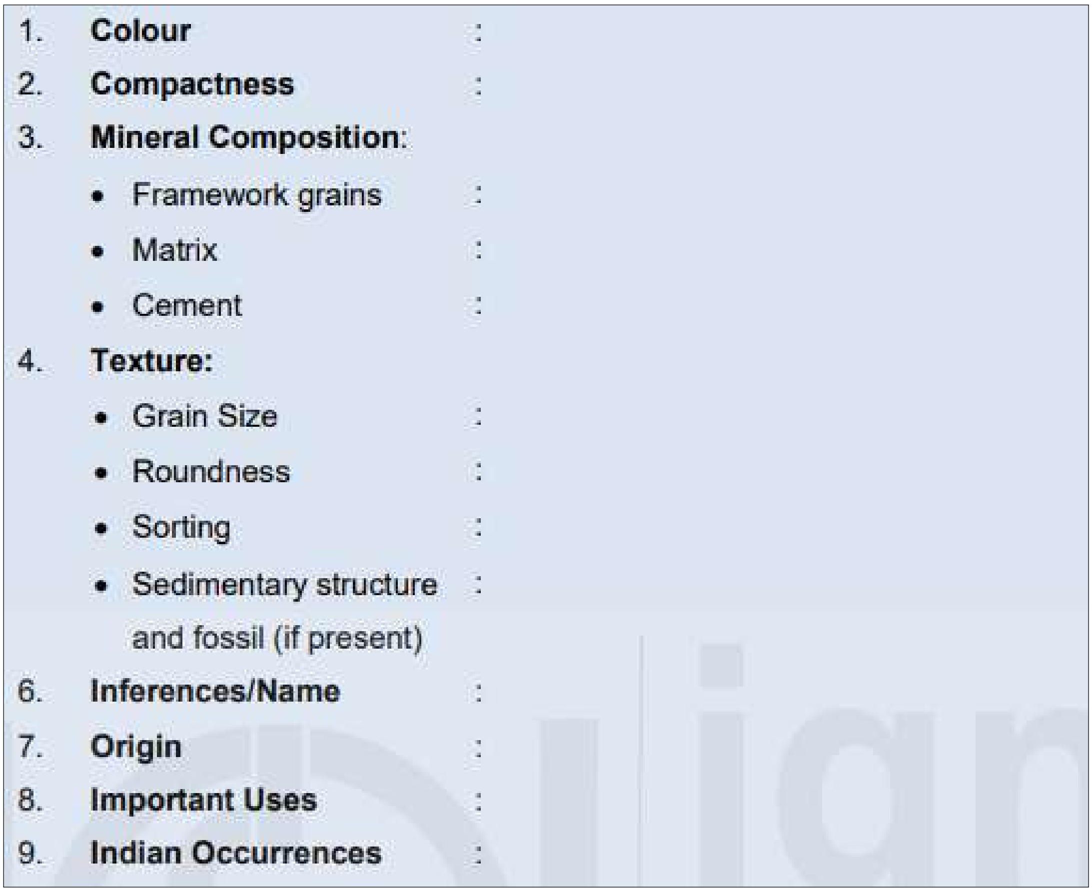
Instructions to perform the experiments and document in your laboratory file: In the laboratory, you will make observations and identify the given hand specimens. Describe the megascopic characters as given in Table 4.

- Take the rock specimen in your hand and observe it carefully.
- Identify the megascopic characters of rock as mentioned in Table 4.
- Examine the minerals in the rock with the help of a magnifying lens and to determine its texture and mineralogical composition.

- Identify whether the rock is a clastic or non-clastic (chemical or biogenic) sedimentary rock.
- If the rock is a clastic sedimentary rock, determine its grain size, roundness and sorting as per the norms discussed in the next section.
- In case of chemical sedimentary rocks, describe whether the rock is crystalline, microcrystalline or clastic/bioclastic.
- Name the given rock specimen on the basis of texture and mineral composition.
- Write uses and occurrences in India.
- You are instructed to draw the sketch of the hand specimen with important characters observed in the laboratory given by your instructor.

Remember!! Descriptions of the hand specimens in the tables and the sketch given in this experiment are generalised. You have to document your own observations and draw the sketches of the hand specimen in the laboratory file.

Table 4: Megascopic Characters of Sedimentary Rocks.



1. **Colour** :
2. **Compactness** :
3. **Mineral Composition**:
    - Framework grains :
    - Matrix :
    - Cement :
4. **Texture:**
    - Grain Size :
    - Roundness :
    - Sorting :
    - Sedimentary structure and fossil (if present) :
6. **Inferences/Name** :
7. **Origin** :
8. **Important Uses** :
9. **Indian Occurrences** :

Megascopic description of Table 3 has been discussed one by one in the following Table 5.

Table 5: Megascopic Description of Sedimentary Rocks

Colour

- Sedimentary rocks exhibit colours of different depending on their mineralogical composition, matrix and cement.
- The red, brown or green sandstone is mainly due to the presence of iron oxides and iron bearing silicates.
- The black or dark gray coloured rocks such as shales contain iron sulfides or organic matter.
- You are advised to take help from the Munsell colour system/chart for recognition of colour accurately and describe with appropriate terms.

Compactness

- It depends upon the mineralogical composition which includes composition of clasts, matrix, cement and texture of the rock.
- Conglomerate and sandstone are hard and compact.
- Sandstone with siliceous cement is more compact than sandstone with calcareous cement.
- Limestone with more silica content is more compact.
- Shales are soft and may be fragile.
- Glass plate or knife blade may help to test this property.

Mineral Compositions

1. Framework grains

- Try to identify quartz, it will appear mostly colourless or in lighter shades.
- Feldspar (can be K-feldspar or plagioclase) will appear to be off-white in colour.
- Mica minerals are flaky in appearance.
- Muscovite and biotite show silvery white and shining black/brown shades respectively.
- Clay minerals present are identified by their soft and friable nature.

2. Matrix

- Chemical sedimentary rocks are mostly a single mineral or mineraloid.
- Limestone, for example, is made up of predominantly of crystalline or cryptocrystalline grains of calcite formed by chemical precipitation.

3. Cement

- The cementing material in clastic rocks is usually secondary silica (arenaceous), calcium carbonate (calcareous), iron-oxides and hydroxides (ferruginous) and clayey (argillaceous). Cement is normally found in well-sorted sandstones.

Texture

1. Grain Size

Grain size is highly variable in the terrigenous sedimentary rocks and is broadly described as coarse, medium or fine. Write average grain size of the clasts in terms of gravel, sand, silt, or clay.

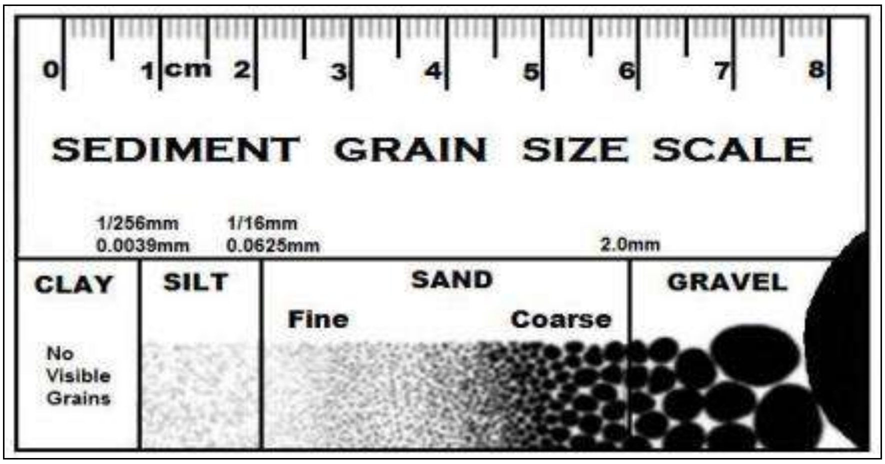


Fig. 13: Sediment Grain Size Scale

2. Roundness

You can use the following Figure to identify the sphericity and roundness of the grains.

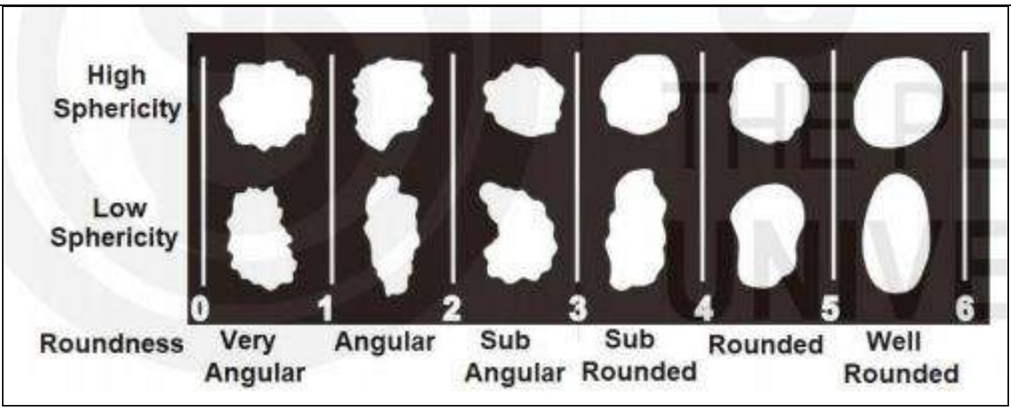


Fig. 14: Roundness Scale and its Relation to Sphericity

3. Sorting

You will describe sorting in terms of well sorted (dune and beach sands), moderately sorted (river and tidal current flat deposits), or poorly sorted (glacial till, debris flow, mud flow) as given below:

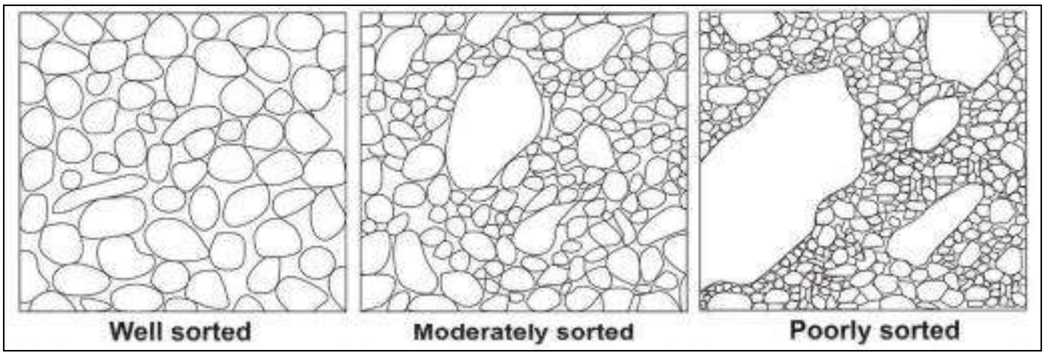


Fig. 15: Sorting of Grains

4. Texture of non-clastic rocks

- Chemical (non-clastic) texture is common in rocks such as limestone, dolomite, rock salt, etc. The grains show an interlocking mosaic of crystals. The non-clastic texture may be crystalline or microcrystalline (micritic).
- Allochemical components are abbreviated to allochems, and are organized aggregates of carbonate, formed within the depositional basin. They include ooids, bioclasts, peloids and intraclasts.
- Ooids are spherical or ellipsoidal grains up to 2 mm in diameter contain regular fine-grained concentric laminae of carbonates developed around a nucleus.

- Peloids composed of fine-grained carbonate recognisable internal structure.
- Intraclasts composed of sediments once deposited on the floor of the depositional basin and later eroded and reworked to form new grains within depositional basin. Bioclasts are the remains either complete or fragmented of hard parts of the carbonate-secreting organisms.

Structure

Hand specimens can show small scale structures such as parallel and cross lamination, graded bedding, rain−drop impressions, mud cracks, etc. These structures provide direct evidence of the processes of sediment transport and energy conditions of the depositional basin.

Fossil content

Fossils of vertebrate and invertebrate animals, plant debris and the tracks, trails or burrows of animals may occur in sedimentary rocks. Fossils can help in finding the relative age of the sedimentary rock and give clues to the type of depositional environment in which the sediments were deposited.

Inference/Name

You have to mention name of the rock identified in hand specimen. The identification be carried out based on colour, compactness, mineralogical compositions, texture and structure of the rock specimen.

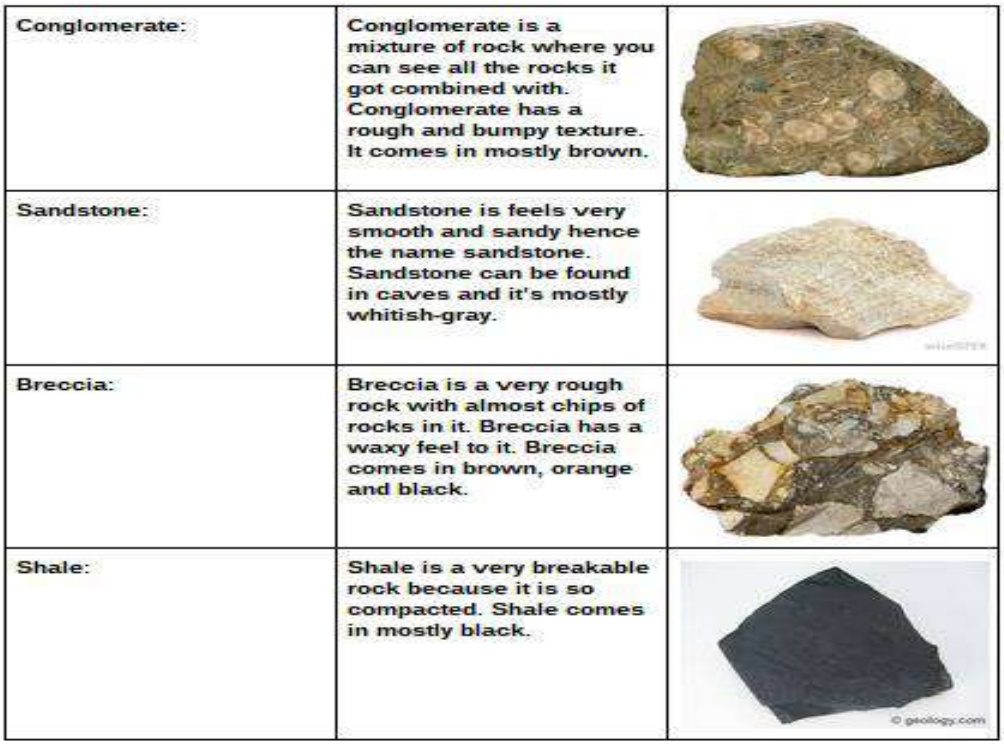
Origin

The study and analysis of the texture, structure and composition of the sediments and sedimentary rocks that enables sedimentologists to comprehend origin of the sedimentary rocks in order to deduce environment of deposition such as ancient shorelines, riverine flood plains, deserts, and swamps.

Important Uses: List important uses of the rock observed.

Indian Occurrences: Give important Indian occurrences of the listed rock types identified by you.

Table 6: Some Examples of Magascopic Examination of Sediments.

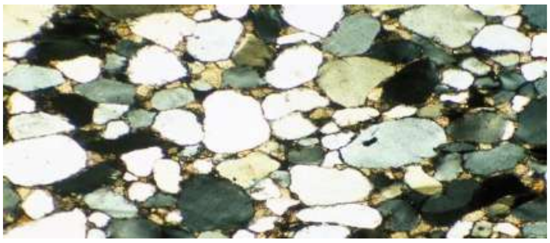


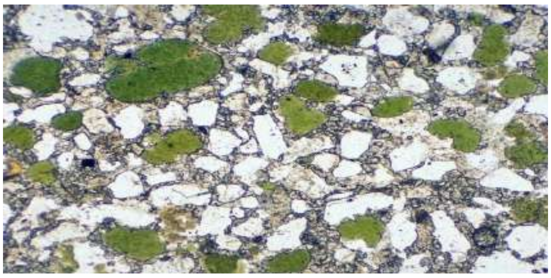
Conglomerate:	Conglomerate is a mixture of rock where you can see all the rocks it got combined with. Conglomerate has a rough and bumpy texture. It comes in mostly brown.	
Sandstone:	Sandstone is feels very smooth and sandy hence the name sandstone. Sandstone can be found in caves and it's mostly whitish-gray.	
Breccia:	Breccia is a very rough rock with almost chips of rocks in it. Breccia has a waxy feel to it. Breccia comes in brown, orange and black.	
Shale:	Shale is a very breakable rock because it is so compacted. Shale comes in mostly black.	© geology.com

3.2. Microscopic Examination of Sediments

Some common rock types as seen under the microscope. These are photomicrographs - very thin slices of rock, seen in plane-polarised light, or between crossed polarisers, when the colours seen are produced by interference of light.

Table 7: Sedimentary Deposits under Microscope

Sedimentary Rock under Microscope	Microscopic Image
Sandstone This sandstone is made of quite well rounded grains of quartz, cemented together by calcium carbonate. Cambrian, NW Scotland. Field of view 3.5 mm, polarising filters.	
Sandstone (with mica) A fairly fine-grained sandstone made of rather	

angular grains of quartz and feldspar (feldspar looks more cloudy). Narrow flakes of mica, seen edge-on, and slightly crumpled, lie on bedding planes. Precambrian (Torridonian), Raasay, Inner Hebrides, Scotland. Field of view 3.5 mm.	
Greensand The green colour that this Cretaceous sandstone has in hand specimen comes from the rounded grains of the mineral glauconite, seen here among quartz grains in a matrix of clay and calcium carbonate. Field of view 3.5 mm.	
Limestone (with fossil fragments) This is a fairly typical limestone deposited in shallow water. A good proportion of the particles are tiny shells and worm tubes, and much of the rest is very small particles of calcium carbonate. Where there was empty space in the sediment, such as inside the worm tube on the right of the picture, larger crystals of calcite have grown. Field of view 3.5 mm, polarising filters.	
Limestone (oolitic) Oolitic limestone is made up largely of sand-sized, rounded pellets of calcium carbonate. In this closer view we can see that some of the pellets have grown by adding layers of calcium carbonate onto a tiny sedimentary grain of quartz. Isle of Skye, Scotland. Field of view 3 mm.	

Limestone (dolomitic) In this limestone, diamond-shaped crystals of dolomite (calcium magnesium carbonate) have grown after deposition, while the sediment was being changed into rock. They replace the fine calcium carbonate mud (dark material in the photo) that makes up the rest of the rock. Field of view 3.5 mm.	
Coal Coal is mostly opaque under the microscope, as you might expect. The red-black material (vitrinite) in the thin section is the part of the coal that appears shiny black in hand sample, and is made from compressed wood tissue. The loop-shaped orange-yellow objects are the flattened large spores of plants. Field of view 3 mm.	

4. Identification of Sedimentary and Bioturbation Structures

4.1. Sedimentary Environment

A sedimentary environment is an area of the earth's surface where sediments get deposited and can be separated physically, chemically and biologically from adjacent terrains. A sedimentary environment may be a site of erosion, non-deposition or deposition. Ancient sedimentary environments can be characterized by deposits of a genetically related succession of laterally and vertically adjacent sedimentary rocks which accumulated under a specific set of environmental conditions. Sedimentary rocks record the geological development of these environments through both space and time.

Table 8: Classification of Sedimentary Environment.

Sedimentary Environments	**Examples**
Continental	Fluvial environment, Alluvial fan environment, Aeolian environment, Lacustrine environment, Glacial environment
Transitional	Deltaic environment, Estuarine environment, Beach environment, Barrier island & Lagoonal environment and Tidal flat environment
Marine	Reef environment, Continental shelf environment, Continental slope & rise environment (all shallow marine environments) and Abyssal plain (deep marine) environments.

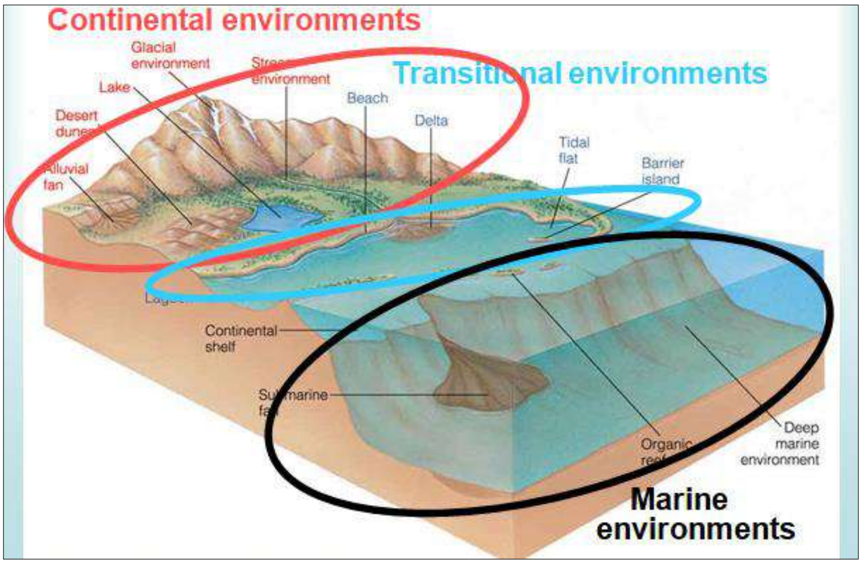


Fig. 16: Sedimentary/Depositional Environment

4.2. Sedimentary and Bioturbation Structures

4.2.1. Sedimentary Structures

Sedimentary structures include features like bedding, ripple marks, fossil tracks and trails, and mud cracks. They conventionally are subdivided into categories based on mode of genesis. Structures that are produced at the same time as the sedimentary rock in which they occur are called primary sedimentary structures.

Sedimentary structures such as cross bedding, graded bedding and ripple marks are utilized in stratigraphic studies to indicate original position of strata in geologically complex terrains and understand the depositional environment of the sediment.

There are two principle types of sedimentary structures which include:

- **Primary sedimentary structures:** occur in clastic sediments and produced by the same processes (currents) that caused deposition which includes plane bedding and cross-bedding.
- **Secondary sedimentary structures:** are caused by post-depositional processes, including biogenic, chemical, and mechanical disruption of sediment.

4.2.2. Bioturbation Structures

As defined by Frey (1975), bioturbation structures or libensspurensare biogenic sedimentary structures that disrupt physical stratifications or rearrange the sediment fabric by the activity of organisms in the form of tracks, trails, burrows and similar structures.

One of the agents of organic weathering, bioturbation is the disturbance of the soil or sediment by living things. It may include displacing soil by plant roots, digging by burrowing animals (such as ants or rodents), pushing sediment aside (such as in animal tracks), or eating and excreting sediment, as earthworms do.

N.B.: Students are required identify and collection of information of the following sedimentary and bioturbation structures during their field visit and have to document their own observations and draw the sketches of the identified structures in the laboratory file.

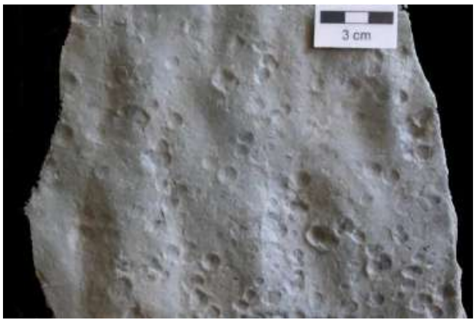
4.3. Identification of Sedimentary and Bioturbation Structures

Physical Structures (Primary Structures)

(Primary sedimentary structures are both inorganic as well as organic in origin, formed during sedimentation or immediately after sedimentation but prior to lithification.)

Bedding A series of visible layers within a rock. Most are originally deposited as horizontal layers (Principle of Original Horizontality) and the oldest layers are usually on the bottom with the layers becoming younger upward (Principle of Superposition).	**Lamination**	Beds less than 1cm is called as laminae. They are characterized by fine grained sediments.	
	Wavy Bedding	Bedding characterized by adulatory bounding surfaces. There is less regular stacking of beds	
	Cross Bedding	Cross bedding is the product of the migration of a mega ripple or sand wave. It may be vary in thickness from 3mm to 30 m.	
	Ripple Bedding	Small ridges formed on the surface of sediment by moving wind or water.	

	Graded Bedding	Graded bedding is common in turbidity current deposits, which form when sediment-water mixtures flow along the seafloor the largest particles settle out and then smaller ones.	
Bedding Plane Markings These are markings found on the lower/upper side of the beds.	**Scour Marks**	They are produced by cutting or scoring action of a current of water flowing over the bottom.	
	Tool Marks	These differ from scour marks in being produced by object carried by the flow interacting with the bed rather than the flow itself.	
	Mud cracks	Polygonal cracks formed in very fine-grained sediment as it dries. Only form in environments	

		where sediment is exposed above water. Tidal Flats, Lake bottoms as the lake dries up, Flood deposited sediment, Desert floors after rainfall	
	Pits and Prints (Raindrop Impressions)	Rain, hail, and spray impressions are small circular to ellipsoidal pits formed in wet mud.	
Deformed Structures Gravitational displacements may occur during sedimentation or shortly thereafter, which deform or alter the depositional structure.	**Load Casts**	Load casts form on the underside of the overlying denser layer (sands, coarse sands, or gravels) which is superimposed on a less-dense hydroplastic layer (muds, silts, or finer sands)	
	Ball-and-pillow structures	These are masses of clastic sediment that take the form of isolated pillows or protruding ball structures.	

<table>
<tr><td></td><td></td><td>These soft-sediment deformations are usually found at the base of sandstone beds that are inter-bedded with mudstone.</td><td></td></tr>
<tr><td rowspan="3"><u>Chemical Sedimentary Structures</u>

These structures formed by chemical processes such as oxidation, reduction, precipitation, and evaporation etc.</td><td>Stylolites</td><td>These are irregular surfaces of one side fit into sockets of like dimensions on the other.</td><td> </td></tr>
<tr><td>Nodules</td><td>A nodule is generally spherical or irregularly rounded in shape. These are typically solid replacement bodies of chert or iron oxides forms during diagenesis of sedimentary rock.</td><td></td></tr>
<tr><td>Concretions</td><td>It consists of round or irregular masses of more resistant rock formed as a result of precipitating around a core</td><td></td></tr>
</table>

		material usually of fossil or grain of different composition.	
<u>Composite Structures</u>	**Geodes**	Geodes are essentially rock cavities or vugs with internal crystal formations or concentric banding.	
	Septaria	These are large size ranging from 10 to 100 cm, distinctly oblate, nodules characterized by a series of radiating cracks that widen towards the center and dies out near the margin that is crossed by a series of cracks concentrate with the margin.	
<u>Biogenic/Bioturbation Structures</u> Biogenic sedimentary structures are those, which are formed by living organisms, interacting with the	**Trace Fossils** (Any traces of plants or animals preserved in a rock.)	**Footprints**	

sediment. Organisms may be animals, which walk on or burrow into the sediment, or they may be plants with roots, which penetrate the sediment, or they may be bacterial/algal colonies, which trap and bind the sediment to produce layered structures.		**Burrows** (Vertical, dark-colored areas in this rock are sediment-filled burrows)	
		Trails	
		Fossilized Dung (Coprolite) A coprolite (also known as a coprolith) is fossilized feces.	
	Bio-stratification (sedimentary layering produced through the activities of organisms)	**Stromatolites** (These are "organo-sedimentary structures" and formed by colonies of sediment-trapping cyanobacteria (commonly called blue-	

	green algae).)	
	Mounds Biogenic mounds made of materials ejected around burrow openings.	
	MISS (Microbial mat induced sedimentary structure) Microbially induced sedimentary structures (MISS) are primary sedimentary structures formed by the interaction of microbes (bacteria, fungi, protozoa, archaea or algae) with sediment and physical agents of erosion, deposition, and transportation.	

5. Sedimentary Environmental Facies Analysis

5.1. Facies Analysis

The term Facies is introduced by Gressly (1838) from the Latin for ‘aspect or appearance’. Reading (1986) defined facies as “a body of rock with specified characteristics”. But the commonest definition of facies runs as “A body of rock characterized by a particular combination of lithology, physical and biological structures that bestow an aspect different from the bodies of rock above, below and laterally adjacent” (Walker, 1993).

Fig. 17: Stratigraphic column on the north shore of Isfjord in Svalbard Norway. The vertical succession of rock types (representing sedimentary facies) reflects lateral changes in paleoenvironment.

Facies Analysis is the fundamental prerequisite for:

- Basin analysis.
- Extrapolation of the external (Extrabasinal) as well as the internal (Intrabasinal, in case of carbonate) causes producing the facies changes, gradual or abrupt.
- Successful implementation of Sequence stratigraphy, particularly in outcrop.
- Extracting an idealized facies model to characterize each depositional environment by combining the features of recent sediments as well as ancient sedimentary rocks.

5.2. Facies Association and Facies Succession

Facies can commonly be grouped into facies associations, which can be defined as “groups of facies, genetically related to one another, and with some environmental significance” (Collinson, 1969). Facies associations are product of a particular sedimentation dynamics.

Facies, or rather, facies associations occur in distinctive successions, characteristically known as facies successions, in which one or more defining parameter changes progressively up-section; like coarsening upward and thickening upward successions.

5.3. Facies Model

A facies model is a general summary of a sedimentary environment, ideally presented in terms of their idealized facies distribution in time and space that make it applicable to different geological study areas. Facies models are thus prepared for following three purposes:

- To sum up general characteristics of products of different sedimentary environments inferred from the study area.
- To distil out universally applicable models for different sedimentary environments.
- To utilize the universal model/s as predictive tools in the study in a new area.

5.4. Types of Sedimentary Facies

1. **Lithofacies:** resulting from the accumulation of particles eroded from older rocks and transported to the depositional site. Example - alluvial facies, bar facies.

2. **Biofacies:** representing accumulations of whole or fragmented shells and other hard parts of organisms. Example – reef facies.

5.5. Methodology of Sedimentary Environmental Facies Analysis

The following is a set of guidelines for the collection and representation of data about a sedimentary environmental facies in the form of a graphic log.

Pre-field method

- Selection of the study area;
- Extensive bibliographic revision of previous studies done in the study area;
- Collection or preparation of map of the study area;
- Preparation of detailed geological map combining photostratigraphic and field mapping procedures;

Field method

- Identification of the best stratigraphic sites for logging (sedimentary logs are considered as the physical expression of vertical stacking of sedimentary rocks in a local or reduced area) of straigraphic sections;
- Collection of stratigraphic information through in extensive fieldwork methods. Following information should be collected during field survey.

Scale: this depends on the detail required. For precise work 1:10 (1cm on the log = 10cm of rock) is used, but if the beds are relatively thick and there is a long sequence to be logged 1:50, (2cm = 1m), 1:100 (1cm = 1m) or even 1:200 (0.5cm = 1m) will be adequate.

Identification of beds: where the bedding planes are clear and the lithology changes between beds this is straightforward. However in some cases it is appropriate to group thin beds together as a single unit. Under these circumstances record the character and range of thickness of the thin beds which make up the unit on the log.

Bed thickness: measure with a tape measure perpendicular to the bedding plane. Bed contacts: note whether the contact between beds is sharp, gradational or erosional (scoured). Care needs to be taken where contacts are gradational as beds can be difficult to define.

Lithology: this is recorded in a column on the log using appropriate ornamentation. The symbols shown are those commonly used, but other ornaments may be used in some circumstances and a key should be given.

Texture (grain size): a horizontal scale on the right-hand side of the lithology column is used to show the grain size from fine on the left to coarse on the right. Changes in grain size (normal or reverse grading) are indicated by tapering the right edge.

Sedimentary structures: these can usually be indicated by symbols within the textures column, although they may also be drawn on the side to make the features clearer. Symbols used should be a simple graphical representation of the feature to make the log easy to understand. If the features cannot be satisfactorily shown by symbols, make a note in the description column.

Cross bedding: the angle of the foreset, the shape of the cross-strata (tangential or tabular, planar or trough), the thickness of the set of cross-strata and the thickness of the individual laminae should be recorded in the description column. The direction of dip of the foreset should be recorded and entered in the palaeocurrent column.

Fossils: symbols for fossils found in the beds should be placed within or alongside the texture column. Use symbols which can be recognised easily. If the fossils are broken, a diagonal line may be drawn through the symbol. The size and orientation of the fossils should be noted. Trace fossils (burrows and trails etc) are important so record the shape, size, orientation and abundance of trace fossils.

Description: any features which cannot be adequately represented in the symbols should be noted in this column. The composition of the rock should be recorded where this can be determined in the field. Record the colour of the rock (fresh and weathered surfaces if different). Make a note of the numbers of any samples collected, photographs taken or if there is additional information in the field notebook on that part of the sequence.

- Collection of samples of materials from each sedimentological horizons for further analysis of sedimentary characteristics such as geometry of materials, magnetostratigaphic studies etc.;
- Collection of photographic evidences of environmental facies.

It is normal practice to use logging sheets prepared with columns and scale already marked on, but under some circumstances a field notebook can be used. Logs drawn in a field notebook may be drawn to scale or a ‘sketch log’ may be drawn. All the appropriate information should be shown on a sketch log, but it is not precisely drawn to scale. Use a sharp pencil, eraser and ruler; it is important that your log is neat, clear and tidy.

Ideally a sedimentary log should be recorded along a continuous line perpendicular to bedding. In practice the nature of the exposure may make it necessary to offset the log along the beds in places; if the offset is significant this should be recorded. If vegetation covers part of the sequence measure the distance obscured and records it as ‘no exposure’.

Start from the bottom and work upwards; this is logical because you will then be working through the sequence in the order in which things happened.

Post-field method

- The post-field method includes data analysis, diagrammatic representation, interpretation and discussions.

The log can be drawn up neatly and accurately in the same style when you return from the field. Two columns should be added to present your interpretations.

Process interpretation: what do the features recorded indicate about the processes of deposition?

Environment interpretation: what environment does this association of depositional processes suggest?

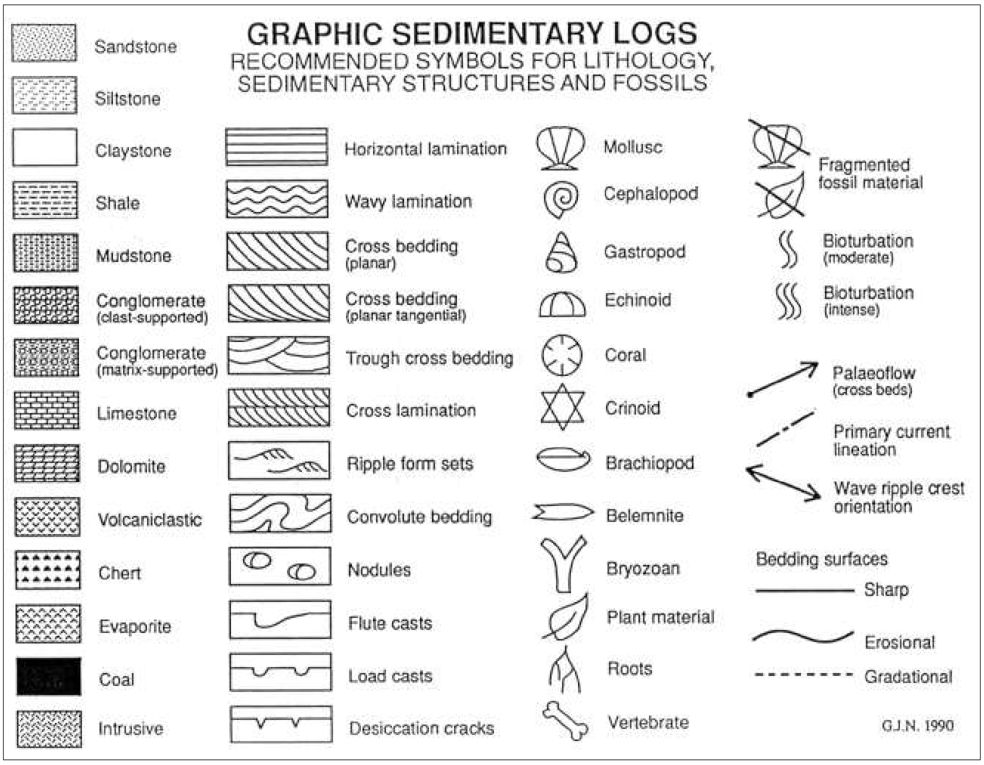


Fig. 18: Recommended symbols for lithology, sedimentary structures and fossils.

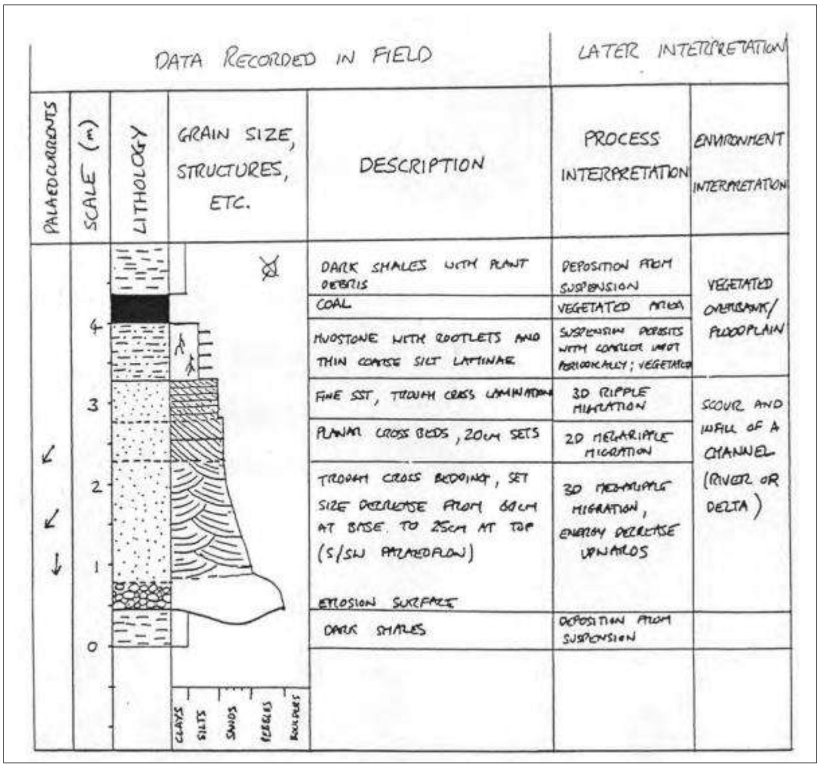
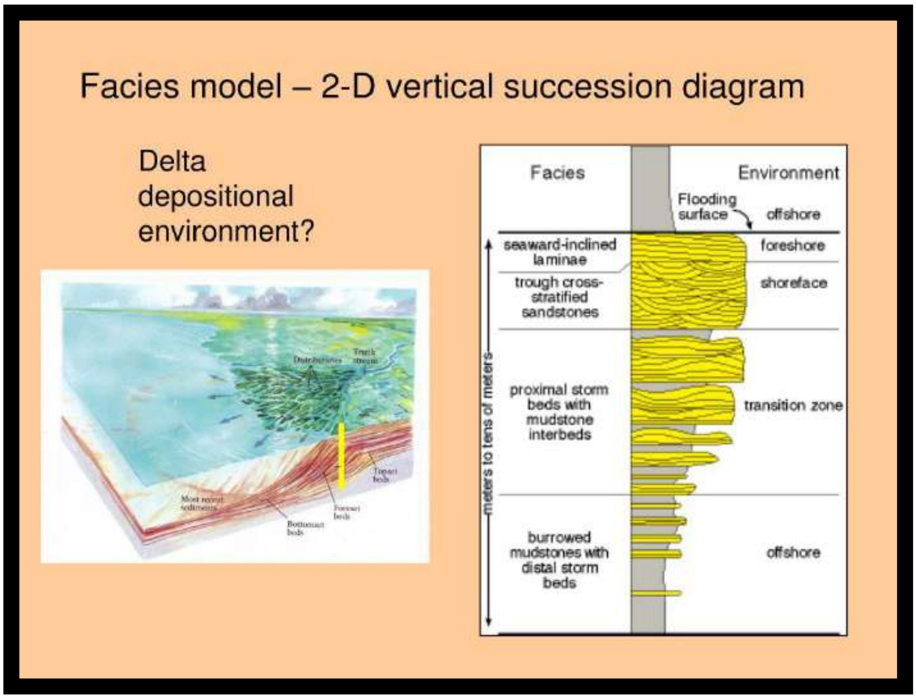


Fig. 19: Data record procedure in the field

Example: Diagrammatic Representation of Sedimentary Facies Environment


Facies model – 2-D vertical succession diagram

Delta depositional environment?

Fig. 18: Sedimentary Facies Environment

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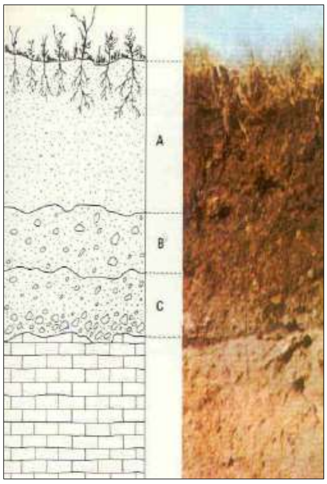
Unit - GEO 196.1: ENVIRONMENTAL MAPPING

Soil Properties Estimation

Soil is a mixture of organic matter, minerals, gases, liquids, and organisms that together support life. Earth's body of soil, called the pedosphere, has four important functions:

- as a medium for plant growth
- as a means of water storage, supply and purification
- as a modifier of Earth's atmosphere
- as a habitat for organisms



Soil Properties:

There are several properties of soil. These are classified in to two broad Categories; -

a) Physical Properties,

b) Chemical Properties.

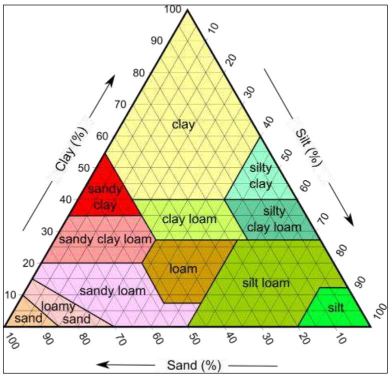
a) **Physical Properties:** There are several physical properties, among which Texture, Structure, Moisture, and Colour.

1. **Soil Texture:**

Soil texture (such as loam, sandy loam or clay) refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the **soil**.

The **texture** of a **soil** is **important** because it determines **soil** characteristics that affect plant growth. Three of these characteristics are water-holding capacity, permeability, and **soil** workability. Water-holding capacity is the ability of a **soil** to retain water.

The particles that make up soil are categorized into three groups by size – **sand**, **silt**, and **clay**. **Sand** particles are the largest and **clay** particles the smallest. Most soils are a combination of the three. The relative percentages of **sand**, **silt**, and **clay** are what give soil its texture.



A. **Method**: Soil is made of both living and dead plants and animals (organic matter) and mineral particles such as sand, silt, and clay. It is said to consist of rocks and minerals (about 45%), water (25%), air (25%), and organic matter (5%).

The profile and texture of soil indicate the relative types of rocks and minerals that compose the soil, chief of which are sand, silt, and clay. Soil texture is an important indicator of the ability of soil to absorb and hold both water and plant nutrients.

Soil type can be classified as follows:

Soil Types by Percentages-

i. Sands: 85-90% sand and<10% clay and silt
ii. Loamy Sand: 70 – 75% sand and <15% clay
iii. Sandy Loams:>52% sand and < 20% clay
iv. Loam: 7-27% clay, 28-50% silt, and<52% silt
v. Silt loam: > 50% silt, 12-27% clay; or 50-80% silt and<12% clay
vi. Clay Loam: 27-40% clay and 20-45% sand
vii. Clay: 27- .40% clay and less than 45% sand and less than 40% silt

Sieve Method:

➢ **Requirements:**

- Balance Machine
- Weighing paper
- Paper towels
- Dry soil samples (at least 100 g. per sample)
- Soil Sieves (4) Note: Soil sieves are available in sets with usually 4 screen mesh sizes (#5 = largest, #10, #60, and #230 = smallest; sometimes #120 is used)
- Shaker Machine.

➢ **Procedure:**

1. Place your weighing paper on the pan of the balance and determine its mass. Record this on your data table. You will need to subtract the mass of the paper for all of your soil measurements.

2. Arrange the soil sieves so that the largest screen size is on the top, followed by decreasing screen size to the bottom.

3. Set the balance to 100g PLUS the mass of the weighing paper. Weigh out that mass of soil that has been broken up into loose particles.

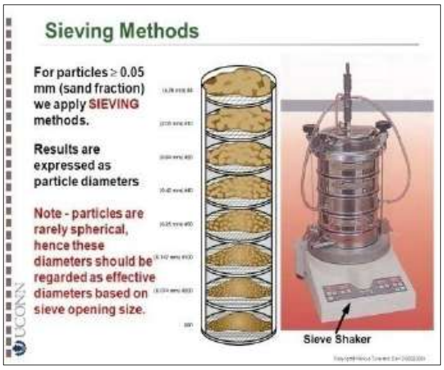
4. Place your soil sample into sieve #1 (the largest). Shake your sample over sieve #2 for two minutes so that sieve #2 collects any smaller soil particles.

5. Place the remaining soil from sieve #1 on the weighing paper and determine it’s mass. Record this on your data table.

6. Shake the soil collected in sieve #2 into sieve #3 (the smallest) for two minutes.

7. Place the remaining soil from sieve #2 on the weighing paper and determine it’s mass. Record this on your data table.

8. Place the soil collected in sieve #3 on the weighing paper and determines it’s mass. Record this on your data table.



Sieving Methods

For particles ≥ 0.05 mm (sand fraction) we apply SIEVING methods.

Results are expressed as particle diameters

Note - particles are rarely spherical, hence these diameters should be regarded as effective diameters based on sieve opening size.

9. Calculate the relative percentage of sand, silt, and clay in the soil sample and record your data in the table below. ‰ % Sand = mass of sand / total soil mass x 100 ‰ % Silt = mass of silt / total soil mass x 100 ‰ % Clay = mass of clay / total soil mass x 100

10. Determine the type of soil based on the relative overall percentage you calculated.

Data Table			
Sample	**Sieve Size/ Mess No.**	**Weight against Sieve**	**Percentage of weight**

Interpretation: Interpret the result according to collected data.

2. Soil Structure

Soil structure describes the arrangement of the solid parts of the soil and of the pore space located between them. It is determined by how individual soil granules clump, bind together, and aggregate, resulting in the arrangement of soil pores between them.

Types-

There are five major classes of structure seen in soils: platy, prismatic, columnar, granular, and blocky. There is also structure less conditions. Some soils have simple structure, each unit being an entity without component smaller units. Others have compound structure, in which large units are composed of smaller units separated by persistent planes of weakness.

a. Platy

In platy structure, the units are flat and plate like. They are generally oriented horizontally. A special form, lenticular platy structure, is recognized for plates that are thickest in the middle and thin toward the edges. Platy structure is usually found in subsurface soils that have been subject to leaching or compaction by animals or machinery.

The plates can be separated with a little effort by prying the horizontal layers with a pen knife. Platy structure tends to impede the downward movement of water and plant roots through the soil.

b. Prismatic

In prismatic structure, the individual units are bounded by flat to rounded vertical faces. Units are distinctly longer vertically, and the faces are typically casts or moulds of adjoining units. Vertices are angular or sub-rounded; the tops of the prisms are somewhat indistinct and normally flat. Prismatic structures are characteristic of the B horizons or sub-soils. The vertical cracks result from freezing and thawing and wetting and drying as well as the downward movement of water and roots.

c. Columnar

In columnar structure, the units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns, in contrast to those of prisms, are very distinct and normally rounded. Columnar structure is common in the subsoil of sodium affected soils. Columnar structure is very dense and it is very difficult for plant roots to penetrate these layers. Techniques such as deep ploughing have help to restore some degree of fertility to these soils.

d. Blocky

In blocky structure, the structural units are block like or polyhedral. They are bounded by flat or slightly rounded surfaces that are casts of the faces of surrounding peds. Typically, blocky structural units are nearly equi-dimensional but grade to prisms and to plates. The structure is described as angular blocky if the faces intersect at relatively sharp angles; as sub-angular blocky if the faces are a mixture of rounded and plane faces and the corners are mostly rounded. Blocky structures are common in subsoil but also occur in surface soils that have high clay content. The strongest blocky structure is formed as a result of swelling and shrinking of the clay minerals which produce cracks. Sometimes the surface of dried-up sloughs and ponds shows characteristic cracking and peeling due to clays.

e. Granular

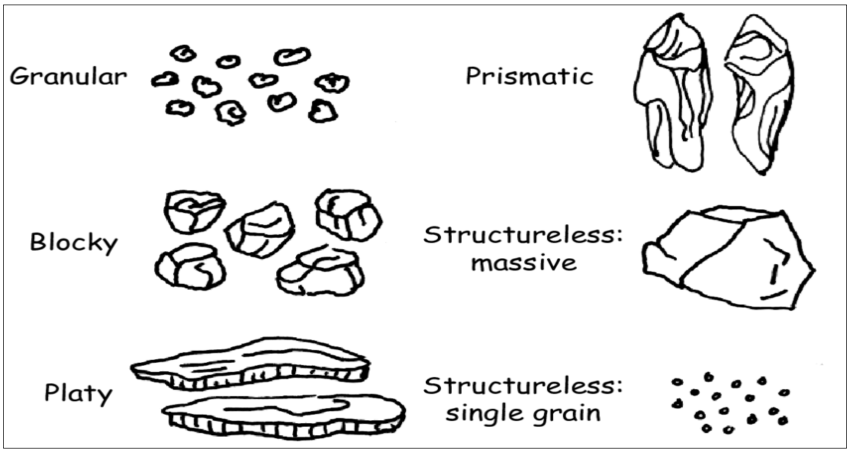
In granular structure, the structural units are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds.

In other words, they look like cookie crumbs. Granular structure is common in the surface soils of rich grasslands and highly amended garden soils with high organic matter content. Soil mineral particles are both separated and bridged by organic matter breakdown products, and soil biota exudates, making the soil easy to work.

Cultivation, earthworms, frost action and rodents mix the soil and decrease the size of the peds. This structure allows for good porosity and easy movement of air and water. This combination of ease in tillage, good moisture and air handling capabilities, and good structure for planting and germination, are definitive of the phrase good tilth.

f. Structure less

Some soils lack structure and are referred to as structure less. In structure less layers or horizons, no units are observable in place or after the soil have been gently disturbed, such as by tapping a spade containing a slice of soil against a hard surface or dropping a large fragment on the ground. When structure less soil is ruptured, soil fragments, single grains, or both results. Structure less soil material may be either single grain or massive. Soil material of single grains lacks structure. In addition, it is loose.



Method:

Soil structure reflects the way in which individual soil particles clump, bind or aggregate together. Natural aggregates that can be clearly seen in the field are called "peds". Clods, on the other hand, are aggregates that are broken into shape by artificial action such as tillage.

Structure is very important since (along with texture) it affects the pore space of the soil. A dense structure will greatly reduce the amount of air and water than can move freely through the soil. Also, it will affect "root penetration or the plant's ability to propagate roots through the soil.
There are four features that may be recorded in the field to describe and define soil

structure

1. **Type** of pedality provides a description of ped shape. There are five major types of structure: granular, blocky, platy, prismatic and structure less (or massive) (see above given figure.)

   Granular, or crumb structures, look like cookie (biscuit) crumbs. They tend to form a more open structure that allows water and air to penetrate the soil. Platy structures look like stacks of dinner plates overlaying one another. Platy and massive structure tends to impede the downward movement of water and plant roots through the soil. Therefore, open structures tend to be better agricultural soils

2. **Size** is the average least dimension of peds, used to define class intervals, i.e. small (0-2 mm), medium (2-5 mm), etc.

3. **Grade** is the degree of development and distinctness of peds, used to express the relative difference between the strength of cohesion within peds and the adhesion between adjacent peds.

4. **Consistency** describes the “feel” of the soil, reflecting relative resistance to pressure.

- **Requirements:** To estimate Soil structure there does not need any formal instrument. If a researcher or student want to record location against every distinct structure, length of plate of platy structure, etc. then there will some requirements as like-
  I. GPS for location estimation
  II. Hand Tape

- **Procedure:** To determine the type, size, grade and consistency of structure:

‘Begin at the original surface (of the intact material on the spade) and break the spadeful of soil gently apart by hand. The criteria used are the size, shape, porosity and cohesion of aggregates and lumps. The assumptions made are that fine and medium crumb-sized aggregates and (large amounts of) porosity are beneficial to root development and crop growth. Overall, the test assesses the quality of the soil as a medium for root growth.

Overall it’s an observational method. A researchers or students have to follow above said method and there need an intense observation.

Soil Colour:

Soil colour does not affect the behavior and use of soil; however, it can indicate the composition of the soil and give clues to the conditions that the soil is subjected to. Soil can exhibit a wide range of colour; grey, black, white, reds, browns, yellows and greens.

Varying horizontal bands of colour in the soil often identify a specific horizon. The development and distribution of colour in soil results from chemical and biological weathering, especially redox-reactions. As the primary minerals in soil parent material weather, the elements combine into new and colorful compounds.

Soil conditions produce uniform or gradual colour changes, while reducing environments result in disrupted colour flow with complex, mottled patterns and points of colour concentration.

Estimation: Soil Colour estimation is directly an Observational method. Through the visible ray a human eye, what types of colour see of a sample or in the field directly, that will be the soil colour.

Soil Moisture:

Soil moisture is the water that is held in the spaces between **soil** particles. **Soil moisture** is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration.

Soil Type	No Irrigation Needed	Dangerously Low Soil Moisture
Fine (Clay)	80-100	Below 60
Medium (Loamy)	88-100	Below 70
Coarse (Sandy)	90-100	Below 80

Requirements:

- Balance Machine
- Weighing paper
- Paper towels
- Hot Air Oven
- Thermometer
- Soil Sample
- Glass plates

- **Procedure:**
  - **i.** Run the hot air oven machine and let the temperature increase up to 100^0C mark.
  - **ii.** During this time period, took 100 gm. soil from collected sample by balance machine.
    Here measuring the weight of taken sample is very important. So carefully measure the weight of sample soil, try to minimize error and the sample would be in natural condition; not dried, not wetted.
  - **iii.** Put this in a glass plates.
  - **iv.** Check the inner temperature of hot air oven by the thermometer. When it will reach up to 100^0C mark, then put the glass plate with weighing soil in to the hot air oven and let these to dry for 12 hours at least 100^0C temperature.
  - **v.** In 12 hour span, two or three times check the inner temperature of hot air oven putting thermometer through proper place (head of hot air oven). If the temperature cross 100^0C mark or below 100^0C mark, then control then power supply of machine and try to control and fixed the temperature always at 100^0C mark.
  - **vi.** After 11 hours, off the power supply of hot air oven machine and let this to cool down.
  - **vii.** After an hour of cooling down, took the dried soil from hot air oven and pore it weighing paper and measured weight again by balance machine.
  - **viii.** Subtracts second weight of soil sample from first weight. The result will be the moisture content of the examined soil sample.

Soil Moisture			
Sample Id	**Weight before Dried**	**Weight after Dried**	**Moisture**

b. Chemical Properties:

The most important chemical properties of soil are pH, Organic Matter, Nitrogen, Phosphorus, and Potassium.

1. **pH:** Soil pH is a measure of the acidity or basicity (alkalinity) of a soil. pH is defined as the negative logarithm (base 10) of the activity of hydronium ions (H^+ or, more precisely, $H_3O^+_{aq}$) in a solution. In soils, it is measured in a slurry of soil mixed with water (or a salt solution, such as 0.01 M $CaCl_2$), and normally falls between 3 and 10, with 7 being neutral.
   Acid soils have a pH below 7 and alkaline soils have a pH above 7. Ultra-acidic soils ($pH < 3.5$) and very strongly alkaline soils ($pH > 9$) are rare.

- **Requirements:**
  - i. Well organized Soil Kit Box
  - ii. Mark Test Tube

iii. Test Tube stand
iv. Rubber strap
v. Soil Sample.

- **Procedure:**

i. Take a clear test tube and pour distilled water up to 5 ml mark.
ii. Put 2 gm. Of soil to the test tube with the scoop provided.
iii. Add 0.5 gm. (1 spoonful) of barium sulphate from container no. 3.
iv. Allow the test tube to stand for 20 minutes with occasional shaking.
v. Add 5 drops of indicator no. 1 from container no. 1 to the above solution close the mouth of the tube with a clean rubber stopper and shake the contents thoroughly. Allow the soil to settle down completely.
vi. Compare the colour of the upper liquid in the test tube with the colour chart no. 1 and find out the nearest match. The match colour will indicate soil pH.
vii. If the colour of the upper liquid in the test tube indicates pH near 6 then repeat the whole experiment using indicator no. 2 instead of indicator no. 1 and match the colour of the upper liquid with colours of the chart no. 2.

2. Organic Matter: Soil organic matter (SOM) is the organic component of soil, consisting of three primary parts including small (fresh) plant residues and small living soil organisms, decomposing (active) organic matter, and stable organic matter (humus).

Soil organic matter serves as a reservoir of nutrients for crops, provides soil aggregation, increases nutrient exchange, retains moisture, reduces compaction, reduces surface crusting, and increases water infiltration into soil.

Soil organic matter impacts the rate of surface applied herbicides along with soil pH necessary to effectively control weeds. Soil organic matter impacts the potential for herbicide carryover for future crops, and amount of lime necessary to raise pH.

- **Requirements:**

i. Well organized Soil Kit Box
ii. Mark Test Tube
iii. Test Tube stand
iv. Rubber strap
v. Soil Sample.

- **Procedure:**

i. Take a clear test tube and pour distilled water up to 10 ml mark.
ii. Add to it 2 gm. Of soil sample with the scoop provided and close the test tube with a clean stopper.
iii. Shake the above thoroughly for 5 minutes and quickly take out 0.5 ml of clay suspended liquid with a clean graduated dropper.

iv. Transfer the liquid from the dropper to a clean test tube and add 1 ml of solution from container no. 15 and 2 ml of solution from container no 16 while swirling the test tube.
v. Keep the test tube for half an hour.
vi. Compare the solution colour with colour chart no 7.

3. Nitrogen:

Nitrogen is macro elements for plants. Plants require more **nitrogen** (**N**) than any other nutrient but only a small portion of the **nitrogen** in **soil** is available to plants; 98 % of the **nitrogen** in **soil** is in organic forms. **Soil** microorganisms convert organic forms of **nitrogen** to mineral forms when they decompose organic matter and fresh plant residues.

Nitrogen is really **important** for plant growth (structure), plant food processing (metabolism), and the creation of chlorophyll. Without enough **nitrogen** in the plant, the plant cannot grow taller, or produce enough food (usually yellow).

- **Requirements:**

i. Well organised Soil Kit Box
ii. Mark Test Tube
iii. Test Tube stand
iv. Rubber strap
v. Soil Sample.

- **Procedure:**

i. Take a clear test tube and fill it with distilled water up to 10 ml mark.
ii. Add to it 2 gms. Of soil sample with the scoop provided and close the test tube with a clean stopper.
iii. Shake thoroughly for 5 minutes and filter it.

(For Nitrate Nitrogen)

iv. Transfer 1 drop of the filtrate solution from step 3 to a clean 2 inch test tube and carefully add 8 drops of solution from container no. 13.
v. Compare the solution’s colour with the colour chart no. 5.

(For Ammoniacal Nitrogen)

iv. Transfer 3 drops of filtrate from step 3 to another clean 2inch test tube and add1 drop of solution from container no. 14.
v. Compare the solution colour with the colour chart no. 16.

4. Phosphorus

Phosphorus is an essential macro-element, required for plant nutrition. It participates in metabolic processes such as photosynthesis, energy transfer and synthesis and breakdown of carbohydrates.

Phosphorus is found in the **soil** in organic compounds and in minerals. Major organic sources of phosphorus include, again, certain manures, as well as **bone meal** and pulverized **rock phosphate**. **Rock phosphate** is a phosphorus-rich rock that is ground into fine particles that release their phosphorus slowly and over the course of many years.

- **Requirements:**

i. Well organized Soil Kit Box
ii. Mark Test Tube
iii. Test Tube stand
iv. Rubber strap
v. Soil Sample
vi. Funnel

- **Procedure:**

i. Take a clean test tube.
ii. Pour solution from container no. 4 in the test tube up to 10ml mark.
iii. Add a pinch of darco from container no. 5 to the above test tube.
iv. Add to above 5 gm. Of soil with the scoop.
v. Close the test tube mouth with the clean rubber stopper. Shake the contents thoroughly for 3 minutes and filter the solution.
vi. Take the filtered solution up to 2 ml mark in another test tube.
vii. Pour 2mlof solution from container no. 6 in the above test tube containing filtered solutions.
viii. Wash the inner side of test tube with about 2ml of distilled water from the wash bottle. Keep it, this will be requiring at step no. 11.
ix. Take 66ml of distilled water in a 100ml beaker.
x. Add to the beaker containing water 0.5 ml. of the solution from container no. 7.
xi. Take 1 ml. of this solution from the beaker and add it to the solution at step no. 8.
xii. Shake the contents thoroughly after closing the tube mouth with a rubber stopper.
xiii. Add distilled water up to 10 ml. mark in the above test tube.
xiv. Compare the colour of the solution with colour chart no. 3.

5. Potassium:

Potassium's unique function is as a regulator of metabolic activities. It is the only nutrient which remains in the plant fluids in a soluble state. In some plants, more is required than any other soil nutrient.

Potassium is highly mobile in the soil, but leaching is minimized by cation exchange and by trapping within clay crystals. Potassium is the Great Regulator. It is active in numerous enzyme systems which control metabolic reactions, particularly in the synthesis of proteins and starches. Micronutrients, which have similar functions, are required only in minute amounts. In contrast, potassium must be present in large quantities, although it seems to be completely unsuited for its role.

- **Requirements:**

i. Well organized Soil Kit Box
ii. Mark Test Tube
iii. Test Tube stand
iv. Rubber strap
v. Soil Sample
vi. Funnel

- **Procedure:**

i. Take a clean test tube.
ii. Pour in it solution from container no. 10 up to 10 ml mark.
iii. Add 5 gms. Of soil with the scoop to the above solution.
iv. Shake the solution for one minute closing the test tube mouth by rubber stopper and then filter. Keep the filtrate for use at step no. 8.
v. Take another clean test tube.
vi. Pour solution from container no. 11 up to 2 ml mark.
vii. Add 6 drops of solution from container no. 12 to the above solution without touching the side of the test tube.
viii. Take 2 ml. of the solution from step no. 4 in syringe.
ix. Inject the solution from the syringe with force into the other solution at step no. 7. Turbidity will develop in the solution after 5 minutes.
x. Compare the turbidity with the colour chart no. 4.

6. Soil profile map

Soil map is a geographical representation showing diversity of **soil** types or **soil** properties (**soil** pH, textures, organic matter, depths of horizons etc.).

Soil Profile is a vertical sequence of recognizable horizons (pedologists use to distinguish from layer, which is used in geology and sedimentology) resulting from the development of a soil (pedogenic processes) over time.

A hypothetical profile would comprise: organic horizons (H and O) and mineral (with some organic matter) horizons (A, E, B), and C (considered by some pedologists as a layer), and R (rock) layer. (Guidelines for soil description fourth edition)

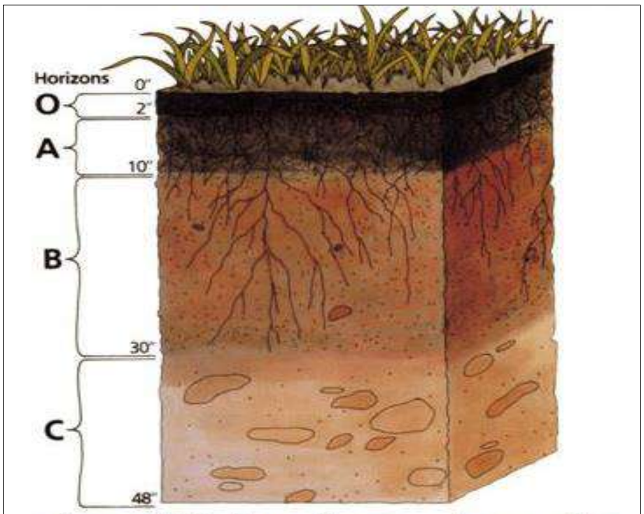
Soil maps are most commonly used for land evaluation, spatial planning, agricultural extension, environmental protection and similar projects.

- **Method:**

i. Hand-drawn soil polygon maps representing distribution of soil types;
ii. Simulated or predicted 2D/3D soil property maps (primary or secondary soil properties);
iii. Simulated or predicted (2D) soil-class maps.

Soil mapping starts with landscape stratification (subdividing terrain into meaningful units, on the basis of geomorphology, lithology, etc.), by means of image interpretation.
Image interpretation takes care of dividing the area (under study) into units, which are related to one or more soil classes, depending on the scale.
Once the sites are known, the following steps follow.-

i. First, describing the soil profile by characterizing on the basis of which soils can be classified.
ii. Second, delineating the distribution/ extension, this is to answer a part of the above questions, by means of extrapolation.
iii. The extrapolation is done by applying geo-pedologic approach, where geomorphology and pedology are combined. “Under similar environments in different places, soils are similar. This regularity permits prediction of the location of many different kinds of soil.” This is the backbone concept of the extrapolation.



Source: USDA Natural Resources Conservation Service.

7. Water Properties Estimation

Water: Water (H_2O) is a polar inorganic compound that is at room temperature a tasteless and odorless liquid, which is nearly colorless apart from an inherent hint of blue. It is by far the most studied chemical compound and is described as the "universal solvent “and the "solvent of life."

It is the most abundant substance on Earth and the only common substance to exist as a solid, liquid, and gas on Earth's surface. It is also the third most abundant molecule in the universe (behind molecular hydrogen and carbon monoxide).

There are several physical, chemical and electrical properties. Among them we have to discussed-

- BOD
- COD
- Dissolved Oxygen
- pH
- Suspended Solid
- Turbidity
- Electric Conductivity.

➢ OPERATION

This is suitablee for operation both in the field and laboratory. When to use in Laboratory connect mains lead at the MAINS socket and its 2 pin plug to the mains electricity supply. During it use in the field, the instrument will be switched ON without mains lead connected to it, it will draw its power from internal chargeable battery. Following procedure may be adopted for its successful operation:

➢ pH MEASUREMENT

pH of natural water varied around 7, generally over 7 (i.e. Alkaline) due to presence of sufficient quantities of carbonates. It increases during the day time mainly due to photosynthetic activity (consumption of carbon dioxide) and decrease at night due to respiratory activity. Factors like exposure in air, temperature and disposal of industrial waters etc. also brings about the changes of pH.

Reverse pH (RpH) is the value obtained by a second pH determination made after the sample is thoroughly aerated. Free carbon dioxide in the sample is partly responsible for initial Hreading. Aeration causes the release of the free carbon-dioxide and measurement ker aeration shows an RpH value higher on the alkaline side of pH scale.

PREPARATION OF pH BUFFER SOLUTION:

- **7 pH Buffer**

Dissolve one buffer tablet of 7pH in 100ml distilled water.The pH of this solution is 7pH.

- **4 pH Buffer**

Dissolve one buffer tablet of 4pH in 100ml distilled water. The ph of this solution is 4pH.

Measurement Procedure

1. Put the function switch to pH mode.
2. Rinse the electrode with distilled water and dry in the tissue paper.
3. Connect the electrode BNC plug at the inputsocket.
4. Put the combination pH electrode in buffer solution 7.00 pH bottle.
5. Set the Temp. Compensation knob to the Temp. Of the buffersolution.
6. Read display value; adjust it with CAL control to 7.00 pH value.
7. Take out the electrode from7.00 pH buffer and rinse it with distilled water and dry it.
8. Put the electrode in 4.00 pH buffer solution.
9. Set the value to 4.00 by adjusting the SLOPE control.
10. Take out the electrode from 4.00 pH buffer, rinse it with distilled water and dry it.
11. Repeats step 4 through 10 once more. You are simply wash electrode with distilled water and rinse with tissue paper. Take reading at display after immersing the electrode in any unknown solution under test.
12. The instrument is now ready to measure pH of any solution.

PRECAUTIONS:

1. Rinse the electrodewith distilled water buffer each test and remove excess water by just touching the bulb with a filter paper. Never wipe out the glass bulb.
2. Never use the electrode in viscous material or suspension; it would clog the fiber junction.
3. When solutions of very wide pH range are measure, allow sufficient time for equilibrium, otherwise it will give sluggish response.
4. Never allow the electrode in the test solution for more than required time.
5. “Filling hole” of electrode should be kept open while operating the instrument.

Conductivity measure:

Some amount of salt is always present in water and soil. Salt up to certain limit is essential for soul fertility. On the other hand excess of salts in soil hinder the crop growth. It is termed as saline soil, the main source of soluble salts present in all soils is the primary minerals, but saline soils usually accumulate the excess salts by drainage seepage from other areas.

Measurement procedure:

- Clean the Cond/TDs cell with distilled water, dry it and connect at COND/TDS input.
- Put the function switch at COND.Position.
- Dip the Cond.Cell in solution under test and determine its value in mS/cm (mMhos/cm).

Preparation of COND/ TDS Standard Solution:

Dissolve 0.5232 gmPotassium chlorides (KCL) AL grade, dried at 180 degree C for 1 hour in distilled water and dilute to 1000 ml. The distilled water used for preparing standards solution has a very low conductivity. The specific conductivity of this solution at 25 Degree C is 1.000 mS/cm (mMhos/cm). The TDS of this solution will be having value of 650 ppm (mh/litre).

➢ TDS Measurement:

A large number of salts are found dissolved in natural waters, the common ones arecarbonates, bicarbonates, chlorides, sulphates, phosphates, andnitrateof Calcium, magnesium, sodium, potassiumiron and manganese etc.

A high content of dissolved solids elevates the density of water, water organism; reduce solubility of gases like oxygen and utility of water for drinking, irrigational and industrial purpose. It is especially an important parameter in the analysis of saline lake, coastal and marine waters. This factor is often expressed in ppm (mg/i) or ppt (g/l).

Measurement Procedure:

1. Cleanthe Cond. / TDS cell with distilled water, dry it and connect to COND/TDSinput.
2. Put the Function Switch at TDS position.
3. Dig the TDS Cell insolution undertest and determine its value on display in ppt (gm/L).

Procedure:

1. COND. /TDS cell may be cleaned by using a warm 50% detergent solution.

2. Platinum plates of the TDS cell must be completely dipped in supernatant solution while taking reading.

3. Scrub the cell electrode with a fine brush. Be careful that the black planitization of the electrode is not damaged by excessive scrubbing.

4. For more tenacious deposits, 2% hydrochloric acid solution may be used by washing the

cell.

5. Rinse the cell in dematerialized water.

6. Do not finger the cell electrode.

➢ Turbidity Measurements:

Clarity of water is important in producing products for human consumption in many manufacturing units, beverages products, food processed and treatment plants. Drawings of surface water supply commonly rely on coagulation setting and filtration to ensure an acceptable product. The clarity if natural body of water is a major determinant of the condition and productivity of that system.

Turbidity in water is caused by suspended matter such as clay;slit finely divided organic and inorganic matter soluble, colored organic compounds and microscopic organisms.

Procedure:

- Take out the Turbidity Sampler (TS) from the brief case.
- Connect the Turbidity Sampler (TS) to the instrument sampler socket through TS connecting lead.
- Allow 2 minutes warm up period after switching ON the Turbidity function.
- Take distilled water or Blank solution in a test tube, insert the test-tube in TS and close the lid.
- Adjust the display 000 by adjusting the Zero set Knob.
- Remove the test tube containing distilled water and fill another test tube containing standard solution of say (200 NTU buffer). Place it in the Turbidity Sampler.
- Take the measurement of the buffer suspension and adjust the calibrate knob to read 200 NTU.
- Again check the display Zero with the test tube containing distilled water.
- Now the instrument is ready to take measurement of any unknown suspension.

Dissolved Oxygen Measurements:

Oxygen dissolved in water, often referred to Do is a very important parameter of water quality is an index of physical and biological process going on in water. There are two main source of DO in water, -

- (i) Diffusion from Air
- (ii) Photosynthetic activity within water.

Procedure:

DO measurement is done by following steps-

i) Do Probe assembly-

Do probe consist of a silver and gold electric cell, an electrolyte tube with ring.

The following procedure may be followed for assembly of Do probe.

1. Be careful to handle its membrane. Fit the membrane on the lower part of the electrolyte tube.
2. Fix the ring on the electrolyte tube covering the sides of the membrane.
3. Fill potassium chloride solution (7.5%) in the electrolyte tube and tightly screw it up with the black plastic cap on silver electrode. While tightening the cap, ensure that there should not be any air bubbles in the tube along the electrode. Now the probe is ready to use.

DO operations:

1. Put the functions switch to DO mode and adjust the display to 00.0 with zero know and insert the DO probe in DO socket. Please keep color code in consideration.
2. Set the zero knob to the extreme left position and CAL knob to extreme right position.
3. Place the DO probe in freshly 2 % sodium sulphite solution, keeping the temp. Knob to actual temperature of the solution. Allow the display to attain equilibrium. If the display does not read 00.0 adjust the zero knob to bring the display to read 00.00 calibrate knob should beat extreme right position.
4. Now calibrate the instrument with known value of DO solution.
5. Take 250ml flask and shake it for 30 second. Remove the stopper and swirl the water back and repeat the procedure 4times.
6. Stoppertheflaskandshakeitfor30Seconds.Removethestopperandswirlthewater back and repeat the procedure 4times.

7. Measure the temp. Of the water and set the temp. Knob at temp of the water in the flask.

8. Hold DO probe in the flask and agitate the water. Note the DO reading given in the table II below for given temperature. If necessary, adjust the display reading with CAL knob to that reading.

NOTE: PLEASE REFER TO THE SATURATION VALUES OF THE DISSOLVED OXYGEN IN DISTILLED WATER ASGIVENINTABLEII. IT SHOWS THE VALUE FOR DISSOLVED OXYGEN WHICH WILL BE OBTAINED WHEN SHAXING THE DISTILLED WATER AT DIFFERENT TEMPERATURE IN THE AIR.

3. Now the instrument is ready to take measurement of DO value of any solution.

Precaution:

1. Since the measurement is based on the diffusion process, the agitation of the solution is a must. Hand shaking of the solution may not give accurate readings. Magnetic stirrer is recommended for this purpose.

2. Movement of the solution should be at least 2ft/sec for accurate measurement.

3. BOD bottle is recommended as a container for measurement of sample solution in the laboratory as DO Probe tightly fits in the BOD bottle and no atmospheric oxygen may dissolve during measurement.

Preparation of Standard Solution:

7.5% potassium Chloride (KCL) Solution-

Dissolve 7.5 gm. of Potassium Chloride (KCL) in 100 ml in distilled water. This position is for filling in the electrode tube and acts as electrolyte between gold and silver electrode.

2% of Sodium Sulphate-

Dissolve 2gm. of Sodium Sulphite in 100 ml in distilled water. This position is oxygen free water and has zero dissolved oxygen.

Maintaining of DO Probe:

1. Do not touch the silver electrode of the probe.

2. The membrane must be having any pin whole puncture. The DO reading will be erratic, if the membrane has puncture.

3. Any accumulation of organic matter in the membrane will affect the calibration of the instrument. CAL. It is advisable to clean the membrane with a soft tissue paper after use.

4. Vegetation density mapping

Topography concerns the shape and character of the Earth's surface, and maps were among the first artifacts to record these observations. In modern mapping, a topographic map or topographic sheet is a type of map characterized by large-scale detail and quantitative representation of relief, drainage, Vegetation, settlement and also transports net work system.

In the concept of Vegetation density mapping mainly based on forest type and forest cover measure by some various methods and techniques. Forest cover in general refers to the relative (in percent) or sure (in square kilometers/square miles) land area that is covered by forests.

According to the Food and Agriculture Organization, a forest is defined as land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.
Forest cover is one category of terrestrial land cover. Land cover is the observed physical features, both natural and manmade, that occupy the earth’s immediate surface ... forest cover is defined as 25% or greater canopy closure at the pixel scale (30-m × 30-m spatial resolution) for trees >5 m in height— *Hansen et al., 2010*

Density in vegetation measurement refers to the number of individuals per unit area (for example plants/m^2). The term consequently refers to the closeness of individual plants to one another. The measure of density is often applied when we want to monitor changes in a given vegetation species over long periods.

Fig. 1 topographical map and field based measurement of forest base parameter

METHODOLOGY:

In the concept of Vegetation density mapping mainly based on forest type and forest cover measure by some various methods and techniques. These are some following major steps-(i)

Preparation of Forest Type Reference Maps using existing thematic maps and other data. (ii)Preparation of final maps depicting spatial distribution of forest types by collecting new information through ground verification and using recent satellite data and incorporating the same on Reference Maps.(iii) Forest cover in general refers to the relative (in percent) or sure (in square kilometers/square miles) land area that is covered by forests.

Preparation of Forest Type Reference Maps:

Forest survey of India(FSI) has huge data on forest resources in form of thematic maps (based on interpretation of aerial photographs and on 1:50,000 scale), field inventory reports and field forms, vegetation type maps (prepared in 1981-83 on 1:2 million scale) and forest cover maps. It is envisaged to integrate these information in a single unit area (grid of appropriate size) to present the most likely forest type in a particular grid.

For this purpose the whole country is divided into a geo-referenced vector layer of' grids using Arc Info software (8.2version). The grid size of 2½′ x 2½′ which on an average encompasses 20 km^2 of area, has been chosen as the most appropriate size. In the conventional field inventory of FSI, a systematic random sampling has been used where the area is divided into grids of 2½′ x 2½′ and all the ground information is collected from the sample plots laid out in this grid. The information of thematic maps available on 1:50,000 scale can be conveniently overlaid on these grids containing 36 grids of size 2½′ x 2½′. Firstly spatial database at country level is created having vector coverage comprising 171,028 grids (Fig. 1). A unique ID is given to each grid so as attach attribute data to it. The description of the attribute data attached to each grid is as follows:

Fig. 2: Nationwide Vector Coverage of Grids of 2½′ x 2½′

a. **Forest Inventory of FSI**: Since its inception in 1965 as PISFR (Pre- Investment Survey of Forest Resources), FSI has carried out field inventory of forest resources. In addition to enumeration of trees, information on soil, species composition, density etc. of each grid in the inventory area is also available in the field forms. FSI has covered more than 80% of countries forest area under field inventory.

b. **Thematic maps prepared by FSI:** Till late nineties, FSI had been preparing thematic maps on 1:50,000 scales based on interpretation of aerial photographs. These maps in all show 48 forest land use classes and 15 non-forest land use classes. Under thematic mapping FSI has covered approximately 72% of the country’s forest area. Though these maps are old but they had provided valuable base line information on species composition as usually there is not appreciable change in species composition of area over a period of time.

c. **Forest species composition maps:** For a study taken up by FSI recently, FSI had prepared forest species composition maps integrating information of thematic maps and inventory records.

d. **Vegetation type maps:** FSI prepared vegetation type maps on 1:2million scale in 1981-83. These maps were partially based on aerial photographs (thematic maps) and partially on inputs received from State Forest Departments. These maps also have provided valuable information in preparation of forest type reference maps.

e. **Latest ground truth information:** In accordance with its mandate, FSI carries out assessment of forest cover on a 2-year cycle and generates forest cover maps. These maps are based on interpretation of satellite data and extensive ground truthing is done before preparing final maps. In each cycle about 2500 points in the forest areas are visited for ground truthing. In the ground truth field forms, information on species composition is also collected

f. **Soil Maps:** Soil maps prepared by National Bureau of Soil Survey and Land Use Planning on 1:1million scale has been procured. These maps have been scanned and are being used to delineate forest types where soil composition is playing a significant role in classification of forest types.

g. **Spatial Information on Climate:** Information on temperature and rainfall on a 10’ x10’ grid size has been obtained from the Centre for Ecological Sciences, Indian Institute of Science, Bangalore. The mean annual values have been used as attribute climate data for each grid.

h. **Forest type maps prepared by other organisations:** In the year 2002, IIRS (Indian Institute of Remote Sensing) produced Biodiversity characterization maps of parts of the country like Andaman & Nicobar Islands, North Eastern region etc., Similarly, mapping work has been done by the French Institute of Pondicherry in the Western Ghats region. These maps will be used to update the reference map. Fig. 3 describes methodology of Stage 1 in brief.

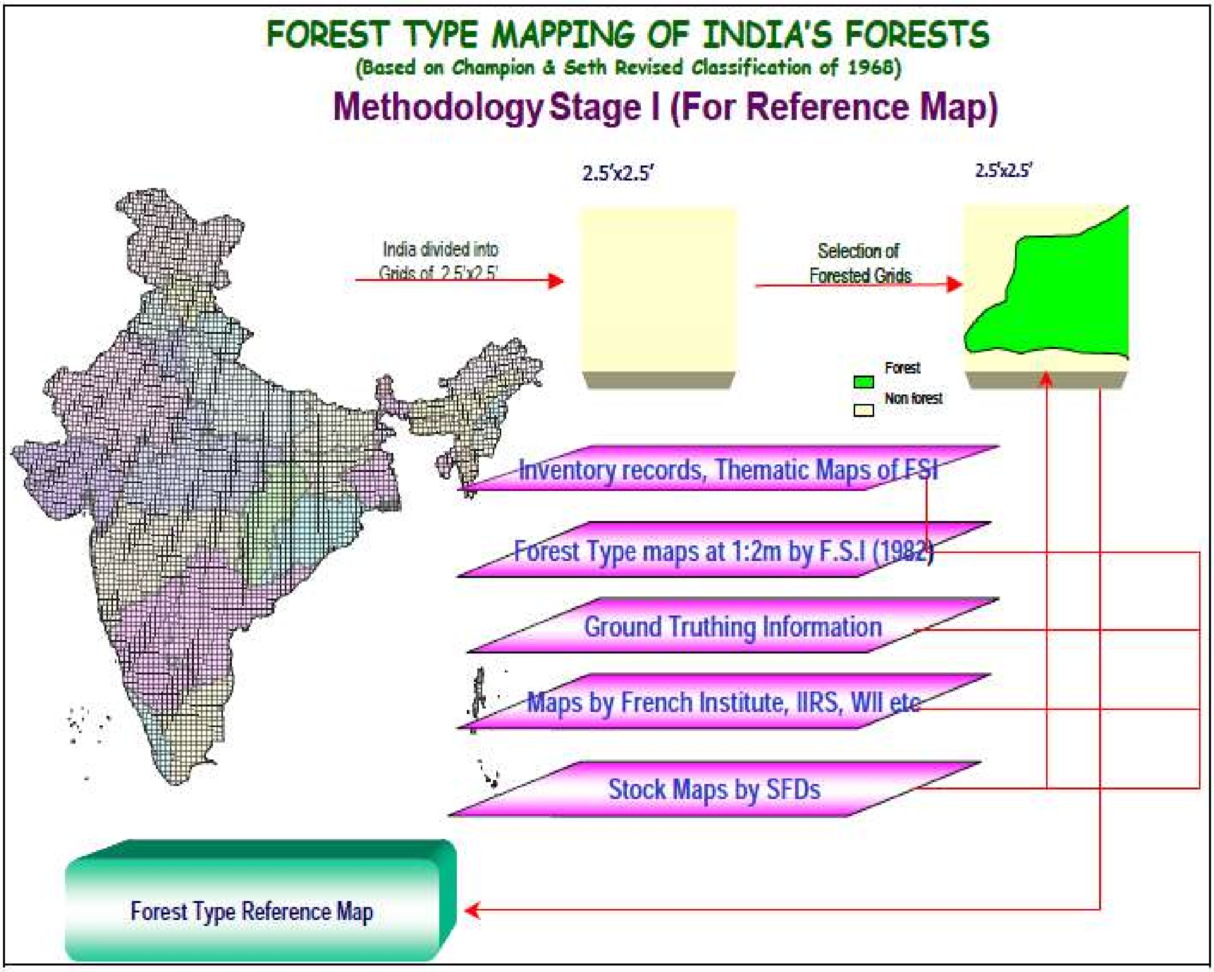


Fig. 3. Methodology for Stage I for Forest Type Mapping.

Preparation of final maps using new data:
The grid based forest type reference maps are being used for extensive ground verification using GPS. During ground verification, ancillary information from the State Forest Departments as available in working plans, stock maps, species composition, forest types, soil, climate, past treatment etc are also being collected. The latest satellite data of IRS 1D (LISS-III) with a spatial resolution of 23.5m X 23.5m for the year 2002 will be used for forest type classification. Multi temporal satellite data including that of dry season and high resolution data will also be used in specific cases. Digital image processing is being done using ERDAS Imagine Professional software (latest version). Following steps are being used in the digital image processing:

1. **Geometric corrections:** Images (False Colour Composites-FCC) in digital forms are first downloaded onto the computers and then registered geometrically using appropriate numbers of GCPs (Ground Control Points) of corresponding Survey of India (SOI) toposheets on 1:50,000scale. The area of interest (i.e., the District) is then extracted by overlaying digitized boundary of the district.

2. **Digital Image Processing:** FCC of the extracted area is then digitally interpreted using a hybrid approach consisting of unsupervised as well as supervised classification using maximum likelihood classifier algorithm. Ortho-rectification and NDVI (Normalized Density Vegetation Index) programmes are also run wherever needed. Rule based classification has been used in areas where topographical features and soil play dominant role in deciding forest type. The NDVI is used not only to detect spatial pattern of biodiversity but also the distribution of biophysical parameters as difference in vegetation type are primarily due to variation in soil, moisture, temperature and rainfall.

3. **Editing of Classified Forest Type Maps:** Classified forest type maps will be further edited on the basis of ground information, data on soil, climate, altitude etc Based on this post classification editing and refinement, final forest type maps will be produced on 1: 50,000 scale.

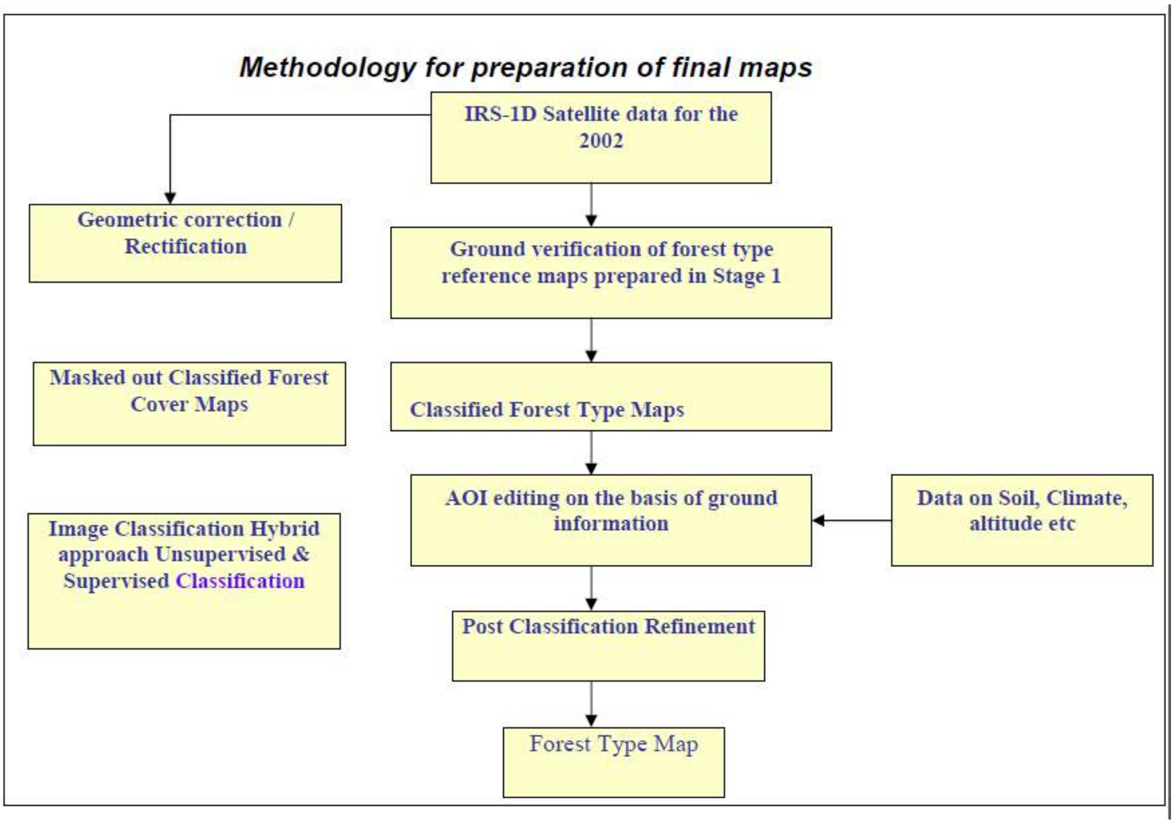


Fig 4. Shows methodology of Stage 2 in brief.

(a) Interior (d) High

(b) Edge (e) Medium

(c) Exterior (f) Low

Fig. 5. Forest Density in a field orientation

Preparation of Forest Density Reference Maps:

Density in vegetation measurement refers to the number of individuals per unit area (for example plants/m2). The term consequently refers to the closeness of individual plants to one another. The measure of density is often applied when we want to monitor changes in a given vegetation species over long periods.

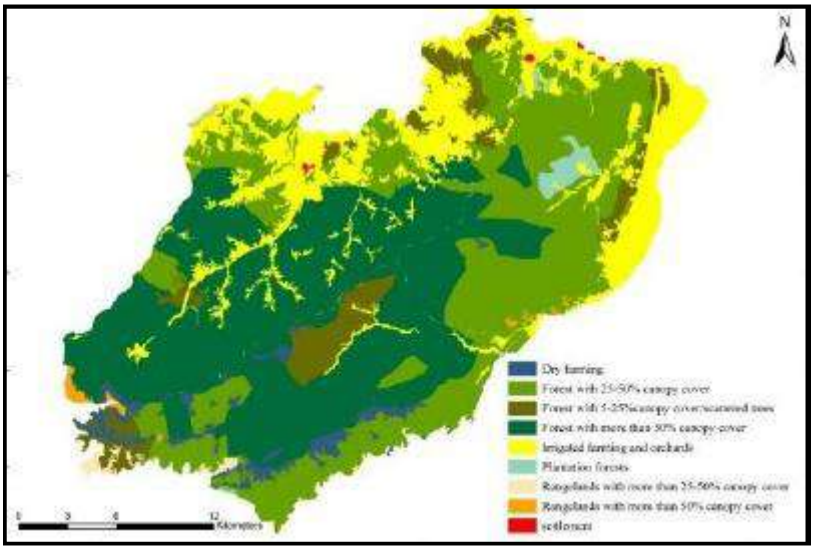


Fig 6. vegetation density map by using cartographic techniques

Measure density within a quadrate by counting the number of individuals and dividing by the quadrant's area. Density can be measured for all species or separated into the density of individual species or species groups. Usually, individual plants are counted only if they are rooted within a quadrat. Measuring vegetation characteristics per area by following methods:

a. Measuring vegetation in quadrats
b. Measuring density
c. Measuring cover in quadrats
d. Making and using quadrats
e. Line and point intercept methods of measuring cover
f. A final note on overlapping plants

a. Measuring vegetation in quadrats:

To make measurements per area, you must somehow delineate areas (with just a few exceptions). The simplest way to delineate an area is with a quadrat frame. You then take your measurements within this quadrat. Measurements from multiple quadrats properly distributed through the community will allow you to extrapolate from your quadrats measurements to the whole community.

b. Measuring density:

Density is the number of individuals per area. You measure density within a quadrat by counting the number of individuals and dividing by the quadrat's area. Density can be measured for all species or separated into the density of individual species or species groups. Usually, individual plants are counted only if they are rooted within a quadrat.

c. Measuring cover in quadrats:

The most common measure of plant abundance is cover. Remember that cover is the proportion of the ground obscured by a species's aboveground leaves and stems (and flowers). (Cover can also be measured for the whole community by not categorizing plants into species.) Cover is popular because it can be measured quickly yet it reflects a plant's structural importance. Sometimes it is easiest to estimate cover by thinking directly what proportion of the quadrat is being covered. This works well when cover is consolidated (not scattered over the quadrat) and cover is between 15% and 85%. The figure shows how this system works. In your mind you divide the quadrat into halves or quarters (or sometimes eighths). In this example, you can see that the plant almost covers one quarter, and the cover that overlaps the edges of the quarter is about the size of the uncovered area within the quarter. Therefore, you can estimate the plant's cover to be around 25%. (Remember, you ignore the parts of the plant outside the quadrat.)

"Dividing down" a quadrat

Fig.7. Measure of vegetation by quadrat methods.

d. Making and using quadrats:

Size and shape:There are no "rules" dictating quadrat size and shape. But using the wrong size or shape will drive you to distraction! The key is to pick a quadrat size and shape that is efficient to use in the field, producing the most information with moderate effort.

Quadrat size: There is no perfect way to pick the best quadrat size. Some texts suggest quadrat sizes for different types of vegetation. But it is better if you understand the issues behind these recommendations, so you can make the right decisions about quadrat size for your own studies.

Quadrat sizes suggested by Cain and Castro (1959) for sampling different life forms (after Barbour et al. 1998)

Life form	Mosses	Low herbs	Tall herbs or low shrubs	Tall shrubs	Trees
Quadrat area (m^2)	0.01-0.1	1-2	4	16	100

It most studies, there is a tradeoff between size and number of quadrats. That is, the more time you spend at each quadrat, the fewer quadrats you will be able to sample from. Decisions about quadrat size depend on this tradeoff, on the need for good interspersion, and on practical concerns in the field. Consider two types of vegetation studies. In the first, imagine you are studying grass seedlings in Willamette Valley prairies, with many of the plants so small that you will need to put your eyes very close to the ground A 10-m^2 quadrat would be impractical in such a study because it would take so long to sample each one that you would have time for only a few quadrats. With just a few quadrats, it is likely that your samples would have poor interspersion. Another difficulty is that it would be nearly impossible to keep track, while examining 10 m^2, of what parts you had already searched. A smaller quadrat size would be much better in this case, something like 30 cm by 30 cm shown at right.

e. Line and point intercept methods of measuring cover:

The line intercept method works best when measuring the cover of plants with distinct crowns, such as sagebrush in the shrub-steppe. The method works by measuring the proportion of the line being intercepted by the species being measured.

f. A final note on overlapping plants:

Plants in nature are almost always overlapping. How this affects the measurement of cover depends on whether the overlap is of the same species or of different species. When measuring cover of single species, you look at its overall cover, ignoring overlap. But if a plant of species A is overlapped or obscured by the cover or another species, does that mean that the plant has less cover? The answer is that it doesn't. You count the cover as if the other species were not even there.

5. Association between soil parameters, vegetation types and density

Soil–vegetation relationship being the product of the same environment, soil and vegetation are mutually associated with each other, but the relationships between edaphic properties and vegetation characteristics are still far from clear.The effects of soil on the vegetation differed between the two formation types. Such singularity in the soil–vegetation relationships has also been reported to distinct forest types, namely rainforests and dry forests. Soil characteristics were mostly important in the savannic formation habitats, showing a significant relationship with all vegetation parameters and online supplementary. As soil characteristics differ between the types of plant formation, such difference propitiates the singular behavior of the soil–vegetation relationship in each formation. However, in the forest formation habitats, soil characteristics did not influence vegetation features across the habitats. Thus, nutrient and water availability (the latter of which could be accessed through soil texture) might be less limiting in the forest formations than in the savannic, exerting a similar influence on the soil–vegetation relationships in the different forest habitats. As previously mentioned, there was no direct relationship between diversity parameters and soil characteristics in the forest habitats. However, in savannic habitats, aluminum, sand and silt contents were the major soil attributes in relation to vegetation descriptors. The soil–vegetation relationship in such diverse landscapes is important from the conservation biology point of view because define habitat preference, and plant structure and diversity supported on each soil type and habitat formations; i.e. richest habitats in both plant and soil nutrient could sustain greater animal diversity and be preferable to conservation, whereas poorest habitats in both plant and soil nutrient could be preferable for cases of restoration. We believe that information provided here support the execution of proactive plans for the maintenance of biodiversity. In our study, besides verify differences in plant structure among formations, we noticed that diversity is range distinctly between savannic and forest communities. Therefore, future studies in tropical landscapes need to include the distribution of species and their respective abundances in relation to edaphic variables in order to better understand the processes involved in the soil–vegetation relationship, especially in ecotonal areas. A review of basic concepts of soil and vegetation development indicates that vegetation and soils are mutually associated with each other, both being the product of the same environmental variables. The mutual association is between the whole soil and vegetation, not individual soil properties and vegetation. Soils and vegetation have a reciprocal relationship. Fertile soil encourages plant growth by providing plants with nutrients, acting as a water holding tank, and serving as the substrate to which plants anchor their roots.

Soil moisture:

Objectives:

1. Understand the methods of soil moisture determination.
2. Soil moisture levels should determine timing of irrigation.
3. Soil moisture can be estimated by feel and appearance of the soil.
4. Tensiometers or resistance blocks also may be used to estimate soil moisture.
5. Know how to measure soil water contents on a mass and volume basis.

Soil moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as percentage.

Almost all soil tests natural moisture content of the soil is to be determined. The knowledge of the natural moisture content is essential in all studies of soil mechanics. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field.

As water is the most limiting factor in the soil, soil moisture determination is of major significance. Soil moisture influences crop growth not only by affecting nutrient availability, but also nutrient transformations and soil biological behavior. Therefore, soil moisture is routinely measured in most field trials. While it can be assessed in the field by neutron probe, the gravimetric approach is more flexible, as samples can be readily taken from any soil situation. All analyses in the laboratory are related to an air- or oven-dry basis. And therefore, must consider the actual soil moisture content.

The gravimetric method involves collection of a soil sample, determining the wet weight, drying it, and then weighing it again. Water content is expressed as the mass of water per unit mass of soil. The volumetric method, which is considered a more useful method, involves taking a known volume of soil, weighing it, drying it, and weighing it again. In this case, water content is expressed as the volume of water per unit volume of soil. From this later sampling, one can obtain soil water content as well as bulk density. Knowing the bulk density, the total porosity can be calculated and used to determine the percent saturation and the depth of water in the soil.

Methods to determine soil water content:

1. Feel method.
2. Gravimetric.
3. Tensiometers.
4. Gypsum blocks.
5. Granular matrix sensors.
6. Pressure plate.

Equipment and material:

Container or Beaker, Spatula, Oven maintains the temperature between 105 ^{o}C to 110 ^{o}C, Desiccator, Balance.

Procedure:

1. Clean the containers with lid dry it and weigh empty (W_1).
2. Take the wet soil sample in the container and weigh with lid (W_2).
3. Keep the container in the oven with lid removed. Dry the specimen to constant weight maintaining the temperature between 105 to 110 ^{o} C for a period varying with the type of soil but usually 16 to 24 hours.
4. Remove the sample from oven: Cool in desiccators for at least 30 minutes

and weight of the container with dried soil sample, (W_3).

Data and observation sheet for water content determination:

Sample No.	Can No.	Weight of can empty, g (W_1)	Weight of can and wet soil, g (W_2)	Weight of can and dry soil, g (W_3)	% Soil Moisture

Calculations:

Calculate the moisture content of the soil as a percentage of the dry soil weight.

$$\%\ \text{Soil Moisture} = \left(\frac{W_2 - W_3}{W_3 - W_1}\right) * 100$$

Where:

W_1 = Weight of container empty (g)
W_2 = Weight of wet soil + container (g)
W_3 = Weight of dried soil + container (g)

Where chemical analyses are performed on moist (air-dry) samples, it is convenient to correct the results to an oven-dry basis by use of an appropriate Moisture Factor (MF) calculated as follows:

$$M\ F = \left(\frac{W_2 - W_1}{W_3 - W_1}\right)$$

Soil Texture

Objectives:

1. Define and understand the terms: soil texture, soil textural class, soil separate, sand, silt, and clay.
2. Determine the textural class of a soil by hand texturing.
3. Determine soil texture by mechanical analysis using the pipette method.
4. Determine the soil textural class with a textural triangle.

Introduction:

Soil texture is defined as the relative proportions of sand, silt, and clay separates that make up the soil texture classes described in the soil triangle. Texture is an intrinsic property of soil that is not changed by management practices. Because soil texture relates to the sizes of the individual particles and the relative proportions of the particle size fractions, it is a major determinant of the surface area that can react with the liquid and gaseous phases. Therefore, soil texture affects the nature and extent of physical, chemical, and biological reactions associated with surfaces. Texture also affects the pore volume and pore-size distribution because pores between small particles are smaller than pores between large particles. The pore-size distribution affects water retention and movement, soil consistence, water availability, aeration, shrink-swell, permeability, and many other soil properties.

Soil texture pertains only to mineral particles less than 2 mm in diameter. Organic matter is ignored unless it is high enough to be the dominant component; this has to be removed by H_2O_2 treatment. However, if substantial amounts of $CaCO_3$ are present, actual percentages of sand, silt or clay can only be determined by prior dissolution of the $CaCO_3$. Descriptive adjectives such as gravelly can be added to modify the textural class name if the influence of particles coarser than 2 mm is significant. *Two common classification schemes are;* the USDA. We will use the USDA classification in this course. Particles greater than 2 mm retain very little water if free drainage is allowed. The 0.05 mm boundary is very close to the lower limit at which sieves can be used to separate fractions, and it also near the point at which water will not drain from pores under gravity if the soil is of a uniform particle size with no aggregation. The 0.002 mm boundary is near the practical lower size limit for using settling velocities with centrifugation, and it is near the upper limit for the occurrence of secondary silicate minerals formed from weathering products.

Classifications of Soil Separate	
Name	USDA (mm)
Coarse Fragment	> 2.0
Sand	2.0 - 0.05
Silt	0.05 - 0.002
Clay	< 0.002

The methods of used for particle size analysis or mechanical analysis are:

- Determine soil texture by the feel method
- Determine soil texture by the sieve’s method.

- Determine soil texture by the hydrometer method.
- Determine soil texture by mechanical analysis using the pipette method.

The pipette method measures the actual percent by weight of each particle size class in your sample. The purpose of this method is to determine the quantity of each of the main sand, silt, and clay fractions in samples of soil form each horizon of the soil profile. Sieve will be used to separate the gravel (particles coarser than 2- mm) from the grains less than 2-mm in diameter and the percent sand will be isolated by wet sieving through a set of nested sieves.

Equipment and materials:

Balance, Analytical balance, Spatula, Shaker, Oven, Hot plate, Flasks 250 or 500- ml, Cylinders 25-ml, Cylinders 500-ml, Beakers 50 or 100-ml, Pipette 25-ml.

Reagents:

1. Hydrogen peroxide (H_2O_2), 25%.
2. Sodium hexametaphosphate (Calgon): Dissolve 40 g sodium hexametaphosphate [$(NaPO_3)_6$], and 10 g sodium carbonate (Na_2CO_3) in distilled water, and bring to 1-L volume with distilled water. This solution deteriorates with time and should not be kept for more than 1 to 2 weeks.

Procedure:

1. Weigh 5 g air-dry soil (2-mm) into flask 500-ml.
2. Add 20 to 25-ml of 25 % H_2O_2; Leave the sample for a period of time to stop the emergence of bubbles. *Add the H_2O_2 to digest the organic matter in soil*.
3. Add approximately 100-ml of distilled water.
4. Add 20-ml of sodium hexametaphosphate (Calgon). *Used for separation of soil particles.*
5. Shake for 1 hour.
6. Transfer soil quantitatively from the flask to cylinder 500-ml, add distilled water, using some of this to rinse the flask.
7. Dilute to 500-ml of distilled water.
8. Weight two beaker 50-ml, the first beaker of silt and clay, and the second beaker of clay.
9. Shake the sample vigorously for 20 seconds. Immediately after you cease stirring the sample, begin the time count for 5 minutes.

10. After 5 min, Pull the fraction from a depth of 10 cm with pipette 25-ml from cylinder. Dispense the sediment sample from the pipette into the 50-ml beaker, wash pipette into beaker with distilled water, Place sample in drying oven at 105°C. These steps calculate percentage of silt and clay fraction.
11. Shake again the sample vigorously for 20 seconds. Immediately after you cease stirring the sample, begin the time count for 6.30 hours.
12. After 6 hours and 35 min, Pull the fraction from a depth of 6 cm with pipette 25-ml from cylinder. Dispense the sediment sample from the pipette into the 50-ml beaker, wash pipette into beaker with distilled water, Place sample in drying oven at 105°C. These steps calculate percentage of clay fraction.

Note: Calgon correction factor (CCF), pipette 20 ml of Calgon into three separate beakers. Place in oven until dry, cool in desiccator and weigh immediately. Use the following equation to figure the mean;

$$CCF\ (g) = \frac{\text{Mean}}{\quad}$$

Data and observation sheet for soil texture determination:

Sample No.	Weight of beaker (**silt +clay**) empty, g	Weight of beaker, (**silt + clay**) with sample after drying, g	Weight of beaker **clay** empty, g	Weight of beaker, **clay** with sample after drying, g

Calculations:

$$Weight\ \text{of silt + clay} = (\text{weight of beaker } and \text{ sample after dring}) - (\text{weight of beaker empty})$$

$$Weight\ \text{of clay} = (\text{weight of beaker } and \text{ sample after dring}) - (\text{weight of beaker empty})$$

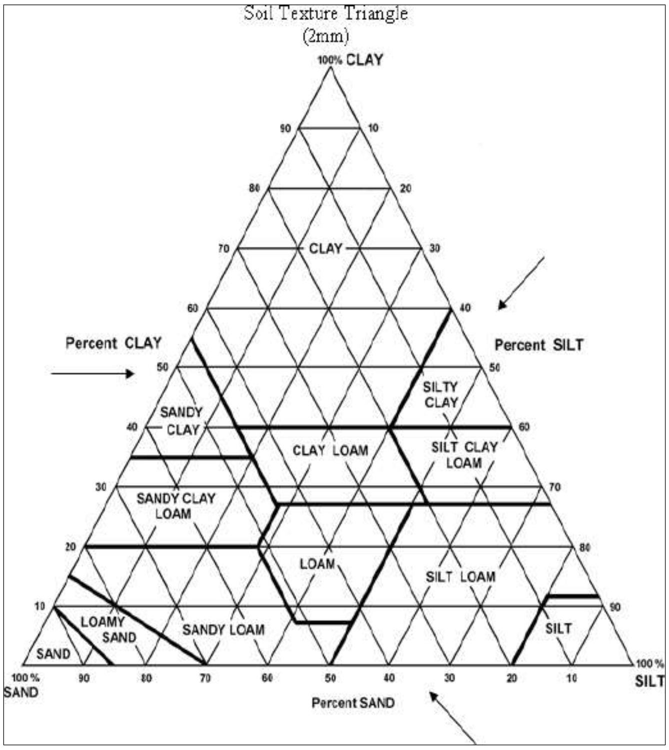
$$Weight\ \text{of silt} = (\text{weight of silt + clay}) - (\text{weight of clay })$$

$$\%\,\text{Clay} = (\textit{Weight}\ \text{of Clay}) * \left(\frac{\text{Volume of Cylinder}}{\text{Volume of Pipette}}\right) * \left(\frac{100}{\textit{Weight of Sample}}\right)$$

$$\%\,\text{Silt} = (\textit{Weight}\ \text{of Silt}) * \left(\frac{\text{Volume of Cylinder}}{\text{Volume of Pipette}}\right) * \left(\frac{100}{\textit{Weight of Sample}}\right)$$

$$\%\,\text{Sand} = 100\% - (\%\,\text{Silt} + \%\,\text{Clay})$$

Sample No.	% Clay	% Silt	% Sand	Textural Class Name



A soil texture triangle is used to classify the texture class of a soil. The sides of the soil texture triangle are scaled for the percentages of sand, silt, and clay. Clay percentages are read from left to right across the triangle (dashed lines). Silt is read from the upper right to lower left (light, dotted lines). Sand from lower right towards the upper left portion of the triangle (bold, solid lines). The boundaries of the soil texture classes are highlighted in blue. The intersections of the three sizes on the triangle give the texture class. For instance, if you have a soil with 33 % clay, 42 % silt, and 25 % sand it falls in the "clay loam" class.

Field Capacity

Objectives:

1. Define and understand the field capacity, permanent wilting point.
2. Measurement of field capacity and water available to soil.
3. Assessing the field capacity of soil is in determining the type of crops to grow in a soil.
4. Judging the capacity of that land to support buildings of various types. The result of these assessments is usually presented as a percentage.

Introduction:

Field capacity (FC): is the amount of soil moisture or water content held in soil saturated (usually in the field) after excess water has drained away and the rate of downward movement has decreased, which usually takes allowed to drain for 12 to 48 hours after rain or irrigation in soils structure and texture.

The time required to reach FC depends on soil texture. Most sandy soils will take 12 to 24 hours, and clay soils require 48 hours or more before drainage becomes negligible. The amount of water retained by the soil depends on the *number and size of pores*. Porosity is governed by; *soil texture*, *soil structure, organic matter, and mineralogy of the soil*. Water from large pores (macropores) will drain under the influence of gravity or a low suction or pressure. High negative pressure or large suction needs to be applied to drain the water from small pores (microspores or capillary pores). The *permanent wilting point (PWP):* is the soil water content below which plants cannot extract sufficient water from the soil to meet their transpiration demand and they are unable to recover from wilting when provided sufficient water. The FC and PWP have been technically defined as the water contents held against tensions, or water that remaining in soils equilibrated at 10-33 and 1500 kPa, respectively. The soil available water holding capacity (AWC) is the water that remains after FC and before the soil driest to PWP (AWC = FC - PWP). The AWC is water that can be readily absorbed by plant roots.

Field capacity is characterized by measuring water content after wetting a soil profile, covering it (to prevent evaporation) and monitoring the change in soil moisture in the profile. Water content when the rate of change is relatively small is indicative of when drainage ceases and is called Field Capacity, it is also termed drained upper limit.

There are also critiques of this concept: field capacity is a static measurement, in a field it depends upon the initial water content and the depth of wetting before the commencement of redistribution and the rate of change in water content over time. These conditions are not unique for a given soil.

Gravitational water: This is the water which drains through the soil under the influence of gravity. Such drainage occurs through large soil pores. Small soil pores have the ability to hold the water against the pull of gravity through the process of capillarity.

Capillary Water: This is the water held against gravity in the small soil pores, or capillaries. This water can be extracted by the plant.

Wilting point: is the soil moisture content where most plants would experience permanent wilting.

Plant available water: This is the water that is considered available for plant use. It is calculated as the difference between the field capacity and wilting point water contents.

Field capacity of a soil is the approximate water content at which the internal drainage of water through the soil profile due to gravity becomes negligible, generally within a few hours to a few days after thorough wetting depending upon soil texture structure and layering (i.e., finer-textured soils take longer to drain and from the result of soil texture most soil sample is clay so it can hold water efficiently.

Field capacity is frequently near the soil water content at 0.1 bar of tension for coarser-textured soils (sands, loamy sands) and 0.33 bar of tension for finer-textured soils (loams, silt loams). One bar is equal to one atmosphere of pressure. Permanent wilting point is usually taken as the soil water content. Permanent wilting point can vary widely for different crops. There is little error in the total available water when a value of 15 bars of tension is used because the amount of water involved at high soil water tension levels is quite small.

Permanent wilting point is the approximate soil water content at which a plant cannot exert enough energy to extract sufficient water from the soil to meet its needs. adding water usually does not revive the plant, or if it does, the plant is seriously stunted and probably will not produce an economic yield. Permanent wilting point is the lower limit of plant available soil water and depends upon both plant and soil characteristics.

Equipment:

Balance, Spatula, Graduated cylinder 100-ml, Graduated cylinder 10-ml, water, Cover or aluminum foil.

Procedure:

1. Weight of empty graduated cylinder 100-ml, (A).
2. Add air-dry soil to the cylinder. Continue filling the cylinder and tapping it until a tapped volume of 100 ml soil is obtained.
3. Weight the cylinder and 100-ml of soil, (B).
4. Measure 10 ml of water and add this slowly to the soil in the cylinder .observe the nature of the wetting front.
5. Cover the cylinder by the foil.
6. Leave cylinder for 16-24hours.
7. After percolation and capillary adjustment have taken place for 24 hours, measure the volume of soil wetted by the water (L ml).
8. Take 5 g approximately from soil wet sample and leave into the oven over night to determine moisture content in air dry soil, (Z).

Data and observation sheet for field capacity determination:

Sample No.	Weight of cylinder empty, (A)	Weight of cylinder and soil, (B)	Volume of soil moistened after add 10-ml H_2O, ml (L)	Percent of dry mass H_2O, (Z)

Calculation:

$$\% \text{ Dry mass } H_2O = \left(\frac{\textit{Wet}\text{ soil} - \text{Dry soil}}{\textit{Dry}\text{ soil}}\right) * 100$$

Determination of Soil Densities and Porosity

Objectives:

1. Define and understand the meanings of the terms bulk density, particle density, and soil porosity.
2. Calculate the bulk density, particle density, and percent porosity of soil.
3. Understand the relationship among these properties and the influence of soil texture, structure, and compaction.
4. Estimate the weight of a soil in a donum plow layer.

A- Bulk Density:

Introduction:

Soil Bulk Density (BD) is defined as the mass of oven-dried solids divided by the bulk volume of the solids plus pore space at specified soil water content. This total volume includes the volume of both solids and pore space.

Bulk density is distinguished from particle density which is mass per unit volume of the solid phase. Particle density excludes pore spaces between particles. As bulk density is usually reported for the <2 mm soil fraction, the mass and volume of rock fragments are subtracted from the total mass and volume.

Bulk density is dependent on soil conditions at the time of sampling. changes in soil swelling due to changes in water content will alter bulk density. soil mass remains fixed, but the volume of soil may change as water content changes.

Bulk density is an extremely useful parameter, as it indicates soil structure and void space. It is required to calculate porosity when particle density is known, to convert weights to volumes, and to estimate weights of soil volumes too large to weigh. It is also required to convert weight based determinations to a volume based figure, which are often, more interesting. For example, the volumetric content of water in a soil layer is obtained by multiplying the gravimetric water content by the product of the bulk density and the volume of the layer.

A medium textured mineral soil that is in good structural condition for plant growth contains about 50% total pore space on volume basis. *This pore space is important for gas exchange Oxygen (O_2) and Carbon dioxide (CO_2) between the soil and the atmosphere, and water storage and movement*. The total pore space consists of the pore spaces between adjacent sand, silt and clay particles and those between aggregates. Therefore, texture and structure are the main factors governing the amount of pore space in soil. Organic matter affects pore space indirectly by improving structure.

Bulk density is an indirect measure of the total pore space in the soil and is also affected primarily by texture and structure. If the aggregation of a particular soil is increased, the total pore space will be increased, and the weight per unit volume or bulk density of the soil will decrease. The bulk density of fine texture mineral soils ranges from about 1.0 to 1.3 g/cm3, and that of sandy soils ranges between 1.3 and g/cm3. The bulk density of organic soils is usually much less than that of mineral soils and may be as low as 0.4 g/cm3. Bulk density and total pore space are readily altered by tillage operations.

Equipment and materials:

Oven, Balance, Graduated cylinder 100-ml, Paraffin, Threads, Hot plate.

Procedure:

1. Take intact clod in its natural state from the soil sample.
2. If roots are present, cut them carefully with scissors.
3. Put it into the oven to dry to a constant weight at 105 ºC during 16-24 hours.
4. Put the clod into the desiccators to cool.
5. Tie the clod with a thread and weight the clod.
6. Immerse it into liquid paraffin (heated on hot plate) to prevent water penetration allow the wax to solidify, and then apply a second coat as soon as possible.
7. Weight the coated clod with paraffin.
8. Immerse the coated clod into cylinder with water and read the volume of displaced water.
9. Dry clod with absorbent paper and weight to check that the weight of the clod is unaltered (due to absorption of water through a small hole in the wax). If the weight has changed, repeat the procedure.

Data and observation sheet for bulk density determination:

Sample No.	Weight of clod with thread, g	Weight of clod + paraffin	Volume of water in cylinder, ml	Volume of water + clod in cylinder, ml

Calculations:

$$M_p = m_{s+p} - m_s$$

$$V_p = \left(\frac{m_p}{\ } \right)$$

$$V_s = V_{s+p} - V_p$$

$$Bulk\ density = \left(\frac{Mass\ of\ soil,\ g}{Volume\ of\ soil,\ \quad ^3} \right)$$

Low bulk density values (1-1.5 g/cm^3) indicate a favorable condition for plant growth. The soil has a good structure and many pore spaces for optimum balance of air and water contents.

High bulk density values (1.8-2.0 g/cm^3) indicate a poor physical condition for plant growth. These soils usually are compacted and contain relatively few pore spaces.

The bulk densities of clay, clay loams and silt loam topsoil may range between 1.00 and 1.60 g/cm^3. Sands and sandy loams usually show variations between about 1.20 and 1.80 g/cm^3, well aggregated loamy soils range between 1.0 and 1.40 g/cm^3. There is a tendency for bulk density values to rise with depth, as effect of evaluation, less aggregation, compaction and organic matter content decrease. Very compact subsoil may have bulk densities exceeding 2 g/cm^3.

Bulk densities above 1.75 g/cm^3 for sands, or 1.46 to 1.63 g/cm^3 for silts and clays, are quoted as causing hindrance to root penetration.

Where the extract bulk density is not known it is common practice to assume an average value of 1.33 g/cm^3.

B- Particle Density (Mineral Density)

Introduction:

Soil Particle Density (PD) is defined the mass of oven-dried solids divided by the volume of the solid particles only. Actually, it is the density of the soil particles, irrespective of the volume of voids between particles. The volume of particle density depends on the type of minerals in the particles, and the content of organic matter in the soil. The particle density of most mineral soils is about 2.65 g/cm^3. It varies little from soil to soil and, therefore, is of little practical significance. It is used with bulk density to calculate soil porosity.

Particle density varies with the type of soil minerals present as well as the amount of organic matter. The particle density of most mineral soils is in the range of 2.60 to 2.75 g/cm^3. Particle density is used in the calculation of pore space and bulk density on a coarse fragment free basis.

Organic matter weighs much less per unit volume than soil minerals. Soils high in organic matter have lower particle densities than soils similar in texture that are low in organic matter. Soil particle density generally increases with soil depth because of the concurrent decrease in organic matter.

Generally, quartz, feldspars, and colloidal silicates dominate the mineral fraction of soils. The particle density of these minerals' averages about 2.65 g/cm^3. When large amounts of heavy minerals, such as hornblende or magnetite, are present, the soil particle density is greater than 2.65 g/cm^3. Soils formed in volcanic parent materials, such as pumice or ash; generally, have particle densities less than 2.65 g/cm^3.

Equipment and materials:

Oven, Desiccators, Balance, Spatula, Graduated cylinder 100-ml, Glass rod, Water.

Procedure:

1. Weight out 25g of oven dried soil sample.
2. Add soil sample into 100 ml cylinder
3. Add 50 ml of water to cylinder. Be sure that no soil material is on the inner walls of the cylinder.
4. Stir thoroughly with a glass rod to displace air.
5. Rinse the stirring rod and inner walls of cylinder from soil material with 10 ml of water.
6. Allow the mixture to stand for five minutes.
7. Record the volume of the soil plus 60 ml water. the difference tow volumes are volume of soil.

Data and observation sheet for particle (mineral) density determination:

Sample No.	Weight of soil, g	Volume of water in cylinder, ml	Volume of water + soil in cylinder, ml

Calculation:

$$Particle\ density = \left(\frac{Mass\ of\ soil,\ g}{Volume\ of\ soil,\ cm^3} \right)$$

Example:

Weight of soil sample 25g. Volume of water 60 ml. Volume of water with soil 69.5-ml. Calculate the mineral density.

C- Porosity (Pore space)

Introduction:

Porosity is a measure of the void spaces in a material, and is measured as a fraction, between 0–1, or as a percentage between 0–100 percent. It is not measured directly but is calculated from the bulk density and particle density.

The term porosity is used in multiple fields including:

- Porosity in manufacturing; in manufacturing of metal or plastic parts, the porosity in the raw material is a serious issue affecting the quality of the resulting products. Porosity may be caused by temperature control problems, material impurities, or other causes in the casting of metal or plastic parts.

- Porosity in earth sciences and construction; Used in geology, hydrogeology, soil science, and building science, the porosity of a porous medium (such as rock or sediment) describes the fraction of void space in the material, where the void may contain, for example, air or water .Porosity is a fraction between 0 and 1, typically ranging from less than 0.01 for solid granite to more than 0.5 for clay, although it may also be represented in percent terms by multiplying the fraction by 100.

- The porosity of rock sedimentary; is an important consideration when attempting to evaluate the potential volume of water or hydrocarbons it may contain. Sedimentary porosities are a complex function of many factors, including but not limited to: rate of burial, depth of burial, the nature of the connate fluids, and the nature of overlying sediments (which may impede fluid expulsion).

- Porosity and hydraulic conductivity: Porosity is indirectly related to hydraulic conductivity; for two similar sandy aquifers, the one with a higher porosity will typically have a higher hydraulic conductivity (more open area for the flow of water), but there are many complications to this relationship. Clays, which typically have very low hydraulic conductivity also have very high porosities (due to the structured nature of clay minerals), which means clays can hold a large volume of water per volume of bulk material, but they do not release water very quickly.

- Porosity of surface soil typically decreases as particle size increases; This is due to soil aggregate formation in finer textured surface soils when subject to soil biological processes. Aggregation involves particulate adhesion and higher resistance to compaction. Typical bulk density of sandy soil is between 1.5 and 1.7 g/cm^3. This calculates to porosity between 0.43 and 0.36. Typical bulk density of clay soil is between 1.1 and 1.3 g/cm^3. This calculates to porosity between 0.58 and 0.51. This seems counterintuitive because clay soils are termed heavy, implying lower porosity. Heavy apparently refers to a gravitational moisture content effect in combination with terminology that harkens back to the relative force required to pull a tillage implement through the clayey soil at field moisture content as compared to sand.

- Porosity of subsurface soil; is lower than in surface soil due to compaction by gravity. Porosity of 0.20 is considered normal for unsorted gravel size material at depths below the biomantle. Porosity in finer material below the aggregating influence of pedogenesis can be expected to approximate this value.

Two types of individual pore space occur in soils: macro and micro. Macro pores permit air and water movement, whereas micro pores retain soil moisture. In sandy soils, macro pores are dominant. Fine-textured soils have preponderance. These soils have a greater water holding capacity as compared to sandy soils, but the movement of air and water is restricted.

Procedure:

The simplest method to determine porosity is through the measurement of bulk density and particle density.

Data and observation sheet for porosity determination:

Sample No.	Bulk Density	Particle Density	% Porosity (Pore space)

Soil Color

Objectives:

1. Define and understand the meaning of the term’s hue, value, and chroma.
2. Use the Munsell book of color to determine the Munsell color notations and color names for moist and dry samples.
3. Identify the soil constituents responsible for soil color.
4. Explain how color relates to soil organic matter and drainage.

Introduction:

Soil color is the most obvious soil property and gives an immediate indication of the condition of the soil system. One of the most apparent characteristics of a soil profile is its pattern of colors. Although the colors have little or no direct significance, there is much that can be inferred from them if they are accurately described. For example, the content of organic matter is approximately indicated by the darkness of the surface soil. Color can provide soil scientists and land users with many clues about the genesis and mineralogy of a soil, provided the observers understand the causes for the various colors and are able to interpret the colors in terms of soil properties. Information concerning organic matter content, mineralogy, drainage, and aeration may be discerned from color and this information applied towards the management and potential uses of a particular soil. It should be stressed, however, that this information must be used with educated caution.

Factors influence the color of a soil:

- Mineral matter derived from the constituents of the parent material; - rocks are broken down to form soils, and sometimes these rocks give their color to the soil. More usually the color of the soil results from compounds such as iron.
- Organic matter; - The colors of soil are derived largely from organic matter. Dark brown to black colors at or near the surface of a soil profile generally indicate the presence of humus, a heterogeneous organic colloid. Sodium content influences the depth of color of organic matter and therefore the soil. Sodium causes the organic matter (humus) to disperse more readily and spread over the soil particles, making the soil look darker.

- The nature and abundance of iron; - Soil color is markedly influenced by the oxidation stage of iron. Yellow and reddish-orange colors in soil are often the result of ferric (oxidized) iron (Fe^{3+}). Yellow, grey and bluish-grey colors result from iron in various forms. Under average conditions of air and moisture, iron forms a yellow oxide imparting a yellow color to the soil. Where soils are well draining or under dry conditions, iron forms red oxides imparting a red color to the soil. Yet in waterlogged soil, with a lack of air, iron forms in a reduced state giving the soil grey/green/bluish-grey colors.
- Moisture content; - Soil color darkens as the soil changes from dry to moist. But longer-term color changes are linked to water relations as well. Careful observation of color can help to identify problems of water logging or leaching. Poorly drained soils are often dominated by blue grey colors often with yellow mottling. Well drained soils will usually have bright and uniform colors.

Iron present is poorly drained soils may also exist as flecks or spots of orange and yellow. This mottled soil color indicates a zone of alternate oxidizing and reducing conditions caused by seasonal fluctuations in the water table. The water table is usually at its highest point during the late winter causing saturation of the lower portion of the profile. Iron is converted to the soluble ferrous form (Fe^{2+}) under these low oxygen (reducing) conditions. During the low rainfall season, the water table recedes and the availability of oxygen in the profile increase. Iron is converted to the insoluble ferric form (Fe^{3+}) under these high oxygen (oxidizing) conditions. The insoluble iron will deposit on ped surfaces as brightly colored iron oxides. The proximity of mottles to the surface of the soil indicates the approximate depth of the seasonally high-water table.

Whitish-grey soil colors may be the result of several processes and explaining their presence depends largely on climatic considerations and the position of the color in the soil profile. Whitish-grey colors found near the surface, or overlying a clay layer, may indicate a zone of extensive leaching. If whitish-grey colors are found in a subsurface horizon of a soil receiving little rainfall, the color may be due to accumulations of lime ($CaCO_3$), gypsum ($CaSO_4$), or other salts. These horizons are commonly found in arid climates where there is insufficient moisture to leach to the soluble salts out of the profile. Lastly, in certain regions, whitish-grey colors may be due to deposits of volcanic ash.

Color is the sensation produced when light of a particular wavelength enters the human eye. Unfortunately, everyone does not perceive nor describe color in the same manner. The color of light is most accurately described by measuring it three principal properties, hue, value, and chroma. Hue refers to the dominant wavelength of the light. Value, also called brilliance, refers to the total quantity of light. It increases from dark to light colors. Chroma is the relative purity of the dominant wavelength of light. It increases with decreasing proportions of white light.

The Munsell Color System is a standardized color designation that specifies the relative degree of the three properties of color. The Munsell color notation can be quickly determined by comparison of a soil sample with a standard set of color plates. The color notation (e.g. 10 YR 6/2) can be translated into a more conventional color name. For instance, 10 YR 6/2 corresponds to the color name light brownish grey.

The nomenclature for soil color consists of:

1) Color name
2) The Munsell notation of color.

Munsell notation for a color chip consists of 3 simple separate variables: hue, value, and chroma.

- **Hue** refers to the color of pigment that must be mixed with black and white (or the proper shade of gray) to produce the color to be matched. Soils range in hue from red (R) through yellow-red (YR) to yellow (Y) with occasionally spots of green-yellow (GY). The continuous range of hue that exists between these major colors is subdivided by number prefixes ranging from 0 to 10. Munsell soil color books usually have pages 10R, 2.5YR, 5YR, 7.5YR, 10YR, 2.5Y, and 5Y. Only one-color pigment (the designated hue) is needed with black and white to produce the colors on any page of the color book.

- **Value** is designated by numbers ranging from 0 for absolute black to 10 for absolute white. Quantitatively, value is equal to the square root of the percentage of light reflected. In the color book, the values range from 2 at the bottom to 8 at the top of each page.

- **Chroma** is an indication of the amount of pigment that must be mixed with the proper value of gray to produce the particular color. Pure gray colors have zero chroma. Increasing brightness is indicated by chromas up to about 8 in soils or to 20 for the total range of color. Chroma is scaled across the color book page with gray colors (zero chroma) on the left side of the page to brighter colors (8 to 10 chroma) on the right side of the page. (Compare this description to the pages in your Munsell book).

Procedure:

Determine the color of the dry samples (these samples were already air dried in lab).

1. Select a pad from the samples provided.
2. Position yourself so that diffuse light comes over shoulder.
3. Select a page from the Munsell color book that contains colors that most closely match your sample.
4. Place the clear plastic page over the color chips. This prevents the color chips and paper from being soiled.
5. Find the color chip that gives the best match with color of the pad .Record the Munsell color notation and the soil color name in your lab book.
6. Place the pad in the plastic spoon.
7. Carefully moisten the pad with water. No free water should be visible on the pad surface.
8. Repeat steps 2 through 6 with the moisten pad.
9. Repeat all steps until you have described all samples.

Data and observation sheet for soil color determination:

Sample No.	Hue	Value	Chroma	Name of Soil Color
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

pH and Electrical Conductivity in water extraction (1:2.5)

Objectives:

1. Define and understand the meanings of the terms soil pH, acidity, electrical conductivity, alkalinity, and salinity.
2. Know the sources of soil acidity.

A- pH

Introduction:

The pH is defined as the negative log of the hydrogen ion activity (**$pH = -\log H^+$**). Since pH is logarithmic, *the H-ion concentration in solution increases ten times when its pH is lowered by one unit.* The pH range normally found in soils varies from 1 to 14.

Soil pH is one of the most common measurements in soil laboratories. Many soil chemical and biological reactions are controlled by the pH of the soil. Soil pH measured in water is the pH closest to the soil solution in the field, but is dependent on the degree of dilution (soil to solution ratio) and the presence of salts. Measuring soil pH in a matrix of 0.01 M calcium chloride ($CaCl_2$), as opposed to water, has certain advantages for agricultural soils, but the addition of the salt does lower the pH by about 1 pH unit compared to soil pH in water.

Standard measurement of soil pH is probably the most commonly used method to characterize soil pH. The use of following advantages for pH measurement:

1. The pH is not affected by the soil to solution ratio used.
2. The pH is almost independent of the soluble salt concentration for non-saline soils.
3. This method is a fairly good approximation of the field pH for agricultural soils.
4. No significant differences in soil pH determination are observed for moist or air-dried soil.
5. One year of storage of air-dried soil does not affect the pH.

Acid soils are rare in semi-arid dry land areas of the world; they tend to occur in temperate and tropical areas where rainfall is substantial; conversely, soils of drier areas are generally alkaline, i.e., above pH 7.0, as a result of the presence of calcium carbonate ($CaCO_3$); they visibly effervesce (fizz) when 10% hydrochloric acid is added drop wise to the soil.

The mass action law states that the product of the concentration of H^+ and OH^- ions is always constant.

$$\mathbf{(H^+)*(OH^-) = 10^{-14}} \text{ or } \quad \mathbf{pH + pOH = 14}$$

According to the range of the pH test in soil there are five different categories as follows: Strongly acid (< 5.0), moderately to slightly acid (5.0 - 6.5), neutral (6.5 - 7.5), moderately alkaline (7.5 - 8.5), strongly alkaline (> 8.5).

Soil pH is important because it influences:

1. Availability of soil nutrients.
2. Solubility of toxic ions in the soil.
3. Physical breakdown of root cells.
4. Cation exchange capacity in soils whose colloids (clay/humus) are pH- dependent.
5. Biological activity.

At high pH values, availability' of phosphorus (P) and most micronutrients. except boron (B) and molybdenum (Mo), tends to decrease.

Two types of pH measurements in soil can be distinguished:

1. The indicator or colorimetric method. (This method is applied in the field as a rapid test for soil pH).
2. The pH-meter method. (This method uses electrode to measure the H^+ ion concentration).

pH reflects whether a soil is acid, neutral, basic or alkaline. Procedure for determining soil pH in a 1:2.5 (soil: water) suspension.

The major sources of soil acidity are:

1. Cultivation of crops.
2. Used fertilization; such as (nitrogen and phosphorus fertilizers).
3. Rainfall and leaching.
4. Organic matter.
5. Acidic cations (hydrogen, aluminum and iron) replace the basic cations (calcium, magnesium, potassium and sodium) on the soil cation exchange complex.

B- Electrical Conductivity (EC);

Soil electrical conductivity (EC) is a measurement that correlates with soil properties that affect crop productivity, electrical conductivity of soil to determine relative salinity is an easy and quick method. EC measures the ability of soil to conduct an electrical charge across a distance. This measurement is recorded as ds/m.

Soil salinity refers to the concentration of soluble inorganic salts in the soil. It is normally measured by extracting the soil sample with water (1:1, 1:2.5 or 1:5 soil: water ratio, w/v) or in a saturated paste extract. However, soil: solution ratios of a 1:1 or wider ratio are more convenient where the soil sample is limited. Such extracts are rapid and salinity is measured by electrical conductivity (EC) using a conductivity meter. The total sail content of a soil can he estimated from this measurement. A more precise method involves evaporation of the aqueous extract and weighing the residue.

Factors affect the electrical conductivity of a soil:

The conduction of electricity in soil takes place through the moisture-filled pores that occur between individual soils particles. The electrical conductivity of soil is depending on the following soil properties:

1. Porosity; - The greater soil porosity the more easily electricity is conducted. Soil with high clay content has higher porosity than sandy soil. Compaction normally increases soil electrical conductivity.
2. Water content; - Dry soil is much lower in conductivity than moist soil.
3. Temperature; - Increasing concentration of salts in soil water will dramatically increase electrical conductivity. Cation exchange capacity (CEC); - Mineral soil containing high levels of organic matter (humus) and/or 2:1 clay mineral such as montmorillonite, illite, or vermiculite have a much higher ability to retain positively charged ions (such as Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+, or H^+) than soil lacking these constituents. The presence of these ions in the moisture-filled soil pores will enhance soil electrical conductivity.

Salinity is an important laboratory measurement since it reflects the extent to which the soil is suitable for growing crops .On the basis of saturation extract if values of:

- 0-2 dS/m is safe for all crops .
- 2-4 dS/m are affected yields of very sensitive crops.

- 4-8 dS/m are affected many crops.
- >8 (above that level) while only tolerant crops grow well.

The electrical conductivity of water is actually a measure of salinity. Excessively high salinity can affect plants in the following ways:

1. Specific toxicity of a particular ion (such as Sodium).
2. Higher osmotic pressure around the roots prevents an efficient water absorption by the plant.

While salinity is largely a concern in irrigated areas and in areas with saline soils, it is not so important in rainfed agriculture. However, with increasing use of irrigation, there will be greater emphasis on EC measurement in the future.

Unit of electrical conductivity is millimhos per centimeter (mmho/cm). In SI units, the conductivity is siemens (1dS /m = 1 mmho/cm). Water with an EC of 0.2 mmho/cm had an EC of 200µmho/cm, 0.0002 mho/cm, or 0.2 ds/m.

For solution in the EC range from 0.1to 5 mmho/cm several empirical relationships have been developed.

- Sum of cations (mmole/L) = EC (mmho/cm) *10
- Sum of anions (mmole/L) = EC (mmho/cm) *10
- Total Dissolved Soiled –TDS- (ppm) = EC (mmho/cm) *640
- Osmotic potential – OP- (bars) = EC (mmho/cm) * (-0.36)

Equipment and materials:

pH-meter, Conductivity meter, pH 7.0 buffer solution, pH 4.0 buffer solution, Balance, Spatula, Flask 250-ml, Shaker, Filter Paper, Funnel, Graduated Cylinder 25 or 50-ml.

Procedure:

1. Weigh 20g air-dry soil (< 2-mm) into a 250-ml flask.
2. Add 50-ml distilled water using a graduated cylinder.
3. Shake for 1 hour on shaker.
4. Filter the solution in graduate cylinder 50-ml.
5. Immerse electrode pH into the flask, pay attention: electrode must be completely immersed in extract, and take reading every sample.
6. Remove the Electrode from the solution, and rinse thoroughly with distilled water in a separate beaker. Keep electrode soaked in buffer solution.
7. Immerse electrode EC in solution, and take reading every samples.
8. Calculate EC multiplying by 2.5.

Calculations:

Sample No.	pH reading	EC reading	EC ds/m	Total Dissolved Soiled -TDS ppm	Sum of cations (mmole/L)	Sum of anions (mmole/L)	Osmotic potential OP (bars)

Notes:

1. Calibrate the pH meter using at least two buffer solutions of different pH val- ues, usually 4.0 and 7.0. First, measure the temperature of the solution and adjust the "temperature" knob. Second, dip the combined electrode in pH 7.0 buffer solution, check for actual pH at measured temperature, and adjust with the "buffer"

knob. Then, dip the combined electrode in the pH 4.0 buffer solution and adjust with "sensitivity" knob. Repeat until pH meter gives correct reading of both buffer solutions.

2. pH is measured in a 1:1 (soil: water) suspension. For special purposes, pH can be measured in a saturated soil paste, or in more dilute suspensions. In some laboratories. pH is measured in a suspension of soil and KCl 1N or $CaCl_2$ 0.01M. The main advantage of the measurement of soil pH in salt solution is the tendency to eliminate interference from suspension effects and from variable salt contents, such as fertilizer residues.
3. Reading are usually taken and reported at a standard temperature of 25°C.
4. Air-dry soils may be stored several months in closed containers without affecting the pH measurement.
5. Readings are recorded in millimhos per centimeter (mmhos/cm) or deci- Siemens per meter (dS/m). The use of the unit deci-Siemens is preferred over the unit millimhos. Both units are equal, that is, **1 dS/m = 1 mmhos/cm.**

Questions:

1. What method is used to determine pH? (1) In the field; (2) In the laboratory.
2. H^+ ions concentration in soil solution is 0.000001g/L. Calculate pH and pOH?
    - pH = - log (0.000001) = 6
    - pOH = 14 – 6 = 8
3. pH of a soil solution is 5. Calculate H^+ ions concentration and pOH?
    - - log x =5x 10^{5-} = 0.00001 g/L.

      pOH = 14 – 5 = 9

Calcium Carbonate

Objectives:

1. Understand the methods of calcium carbonates determination.
2. Measurement of calcium carbonates in soil.
3. Understand the relationship among calcium carbonates properties and the

influence of plant.

Introduction:

Calcium carbonate ($CaCO_3$), a major component of calcareous soils, ranges from a few percent in slightly calcareous soils to more than 80 percent in some extremely calcareous soils. Affect soil physical and chemical characteristics. The presence of carbonates in the soil the form of calcium carbonate (calcite) or magnesium carbonate (dolomite) or mixtures of both, occurs in soils as a result of weathering, or is inherited from the parent material. Most soils of arid and semi- arid regions are calcareous.

It was found that when total $CaCO_3$ was above 20%, active $CaCO_3$ was more than 10%. Carter (1981) gave 11 to 30% total carbonate and 7 to 9% active $CaCO_3$ as the critical levels that adversely affected crop growth.

Soils with free $CaCO_3$ tend to have lower availability of phosphorus and of some micronutrient cations. Was directly related to carbonate content and to the distribution of total and active calcium carbonate between the clay and silt fractions. When total $CaCO_3$ was less than 20 % the retention of those elements was affected mainly by the total amount of carbonates, but, when it was above 20%, nature of the carbonates was more important in governing retention. The active $CaCO_3$ was more than 10% when the total $CaCO_3$ was above 25% in the studied soils. Therefore, one could give the limit of about 10% active $CaCO_3$, which will contribute significantly to the retention of certain essential elements in calcareous soils.

Consequently, $CaCO_3$ equivalent is normally determined in most laboratories. While determine "active" $CaCO_3$, it is less common than "total" CaCO3, being mainly in areas of French influence since it was developed by Drouineau (1942) in France. It basically reflects surface area or reactivity of $CaCO_3$ particles, mainly

the clay-size fraction. Active $CaCO_3$ is usually related to total $CaCO_3$ equivalent, being about 50% or so of the total value.

Physical effects: The active-$CaCO_3$ portion and the distribution of $CaCO_3$ in the different particle size fraction affects the properties (soil-water relationships) of calcareous soil (Deb and Chadha, 1970; Thabet, 1975). Calcareous soils with

15% calcium carbonate content has higher water diffusivity and faster water movement than non-calcareous soils of similar texture. Evidently, $CaCO_3$ assists in the formation of stable soil aggregates. But, increased $CaCO_3$ content (25% or more) tends to precipitate within the capillary tubes causing an increase in the proportion of micropores, thus reducing the percolation of water.

Effect on plants: Continuous horizons of carbonate accumulation in soil profile may prevent root penetration and thus may retard the degree of plant development and reduce the yield. Sys (1975) classified the sensitivity of crops to $CaCO_3$ into three groups as follows:

1. Tolerant crops: wheat, alfalfa, figs, olives and dates.
2. Moderately tolerant crops: barley, clover, cotton, maize, millets, rice, grapes, sugarcane, sugar beet, watermelons, lettuce, tomatoes beans, artichokes, tobacco and onions.
3. Sensitive crops: citrus, banana and potatoes.

There are two methods to estimate the calcium carbonate in the soil:

1. Calcimeter method.
2. Titration method.

Principle

A given weight of soil is reacted with an excess of acid. In this reaction, CO_2 gas is released and the acid not used in the dissolution of carbonates is back-titrated with sodium hydroxide solution (FAO, 1974). Some methods of carbonate deter- mination in soils are based on the collection of CO_2 gas, and the

Measurement of CO_2 pressure which develops if acid is added to a calcareous soil in a closed flask. In the titrimetric method, two equivalents of acid are assumed to react with one mole of $CaCO_3$. Hence, one equivalent of acid is assumed to be equivalent to one-half mole of $CaCO_3$

Equipment and materials:

Balance, Spatula, Flask 250-ml, Shaker, Filter Paper, Funnel, Pipette, Burette with Magnetic Stirrer.

Reagents:

1. Hydrochloric Acid Solution (HC1), 1N: Dilute 82.8-ml concentrated hydrochloric acid (37%) in distilled water, mix well, let it cool, and bring to 1- L volume with DI water.
2. Sodium Hydroxide Solution (NaOH), 1 N: Dissolve 40 g sodium hydroxide in distilled water, and transfer to a 1-L volume, let it cool, and bring to volume with distilled water.
3. Phenolphthalein indicator 1% in 60% ethanol: Weight 1 g phenolphthalein crystals in 100 ml volumetric flask add 60 ml of ethyl alcohol and dilute to volume with distilled water. Shake the flask until the crystals dissolve completely.

Procedure:

1. Weigh 5 g air-dry soil (2 mm) into a 250-ml Erlenmeyer flask.
2. Add 50-ml 1N hydrochloric acid solution (HCl) to the flask with a cylinder.
3. Shake for 1 hour.
4. Filter the solution in flask 250-ml.
5. Take 10 ml by pipette of the filtrate into a 100 ml Erlenmeyer flask.
6. Dilute to 50ml with distilled water.
7. Add 4-5 drops indicator (Phenolphthalein).
8. Titrate with 1N sodium hydroxide solution (NaOH) while swirling the flask, the colorless change to pink color.

Data and observation sheet for calcium carbonate determination:

Sample No.	Weight of sample, g	Total volume of HCl, ml	Volume of HCl, for used titration, ml	Volume of NaOH, ml	% $CaCO_3$

Calculation:

$$\% \, CaCO_3 = \left[\left(V_{HCl} * N_{HCl}\right) - \left(V_{NaOH} * N_{NaOH}\right)\right] * (R) * \left(\frac{100g}{}\right) * 0.05$$

Where:

V_{HCl} = Volume of HCl used for titration (ml).

N_{HCl} = Normality of HCl solution.

V_{NaOH} = Volume of NaOH solution used for titration (ml).

N_{NaOH} = Normality of NaOH solution.

R = Ratio between the total volume of the extract and the extract volume used for titration.

Wt = Weight of air-dry soil (g).

Cations Exchange Capacity (CEC)

Objectives:

1. Define and understand the meanings of the terms cation exchange and cation exchange capacity (CEC).
2. Measure cation exchange capacity and concentration of exchangeable cations in soil.

Introduction:

Cation exchange capacity (CEC), refers to the quantity of negative charges in soil existing on the surfaces of clay and organic matter that is available to bind positively charged ions (cations) for exchanging with the soil solution. Hence the name 'cation exchange capacity'. Any element with a positive charge is called a cation and, in this case, it refers to the basic cations, calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^+) and sodium (Na^+) and the acidic cations, hydrogen (H^+) and aluminum (Al^{+3}).

The amount of these positively charged cations a soil can hold is described as the CEC and is expressed in milliequivalents per 100 grams (meq/100g), (1 meq/100 g soil = 1 cmol/kg in SI system) of soil. The larger this number, the more cations the soil can hold. A clay soil will have a larger CEC than a sandy soil. The CEC gives an indication of the soils potential to hold plant nutrients. Increasing the organic matter content of any soil will help to increase the CEC since it also holds cations like the clays.

CEC is highly dependent upon soil texture and organic matter content. In general. a higher quantity of clay and organic matter has a high CEC. Only a small percentage of the essential plant nutrient cations (Ca^{+2}, Mg^{+2}, K^+, Na^+ and NH_4^+) will be 'loose' in the soil water and thus available for plant uptake. Thus the CEC is important because it provides a reservoir of nutrients to replenish those removed from the soil water by plant uptake. cations in the soil water that are leached below the root zone by excess rainfall or irrigation water are replaced by cations formerly bound to the CEC.

Base saturation refers to the fraction of the CEC that is occupied by the basic cations, Ca^{+2}, Mg^{+2}, K^+ and Na^+. Base saturation is used to manage soil Na^+ and can be utilized to determine soil Mg^{+2} availability. When Na^+ exceeds 15% of the CEC, water and air infiltration into the soil may be reduced and poor growing conditions may result. To overcome this problem Ca^{+2} is added to replace the Na^+ from the CEC. Sodium in the soil water is then be leached out of the root zone by excess irrigation or rainfall. The amount of Ca^{+2} needed to replace the Na^+ is based on the amount of exchangeable Na^+ as well as Na^+ saturation.

Two factors determine the relative proportions of the different cations adsorbed by clays. *First*, cations are not held equally tight by the soil colloids. When the cations are present in equivalent amounts, the order of strength of adsorption is $Al^{+3} > Ca^{+2} > Mg^{+2} > K^+ = NH_4^+ > Na^+$. *Second*, the relative concentrations of the cations in soil solution help determine the degree of adsorption. Very acid soils will have high concentrations of H^+ and Al^{+3}. In neutral to moderately alkaline soils, Ca^{+2} and Mg^{+2} dominate. Poorly drained arid soils may adsorb Na in very high quantities.

Factors that are affected the cation exchange capacity are:

1. Soil texture: It means the amount of clay in the soil, the higher the percentage of clay in the soil have increased the proportion of CEC.
2. The type of metal clay: that the presence of metal in the soil will increase the proportion of the CEC.
3. The amount of organic matter: her best high cation exchange and thus increase the quantity in the soil increases the CEC.
4. The pH of soil: the higher the pH increases the CEC summit because it affects the shipment.

In general, the CEC of most soils increases with an increase in soil pH. Soil pH is a less obvious factor affecting CEC. Soils contain two sources of negative charge, permanent and variable. Permanent charge is located within the structure of the clay particles. Variable charge is located on the edges of clay and organic matter particles. The primary factor affecting the variable charge is pH. changing pH from 5.5 to 6.5 may double the CEC. A pH of 6.5 is the highest pH recommended for most grasses in most situations. Maintaining soil pH near this level provides near optimum CEC and phosphorus availability while providing acceptable conditions for micronutrient availability.

The direct measurement of CEC is costly. Therefore, soil testing laboratories estimate, rather than measure, CEC. Estimates are made by determining the extractable cations (Ca^{+2}, Mg^{+2}, K^+ and Na^+) and estimating H^+ and Al^{+3} from soil and buffer pH measurements. Estimates will be erroneously high in two commonly occurring situations. Firstly, CEC will be overestimated if a soil is sampled shortly after a heavy fertilizer or gypsum application. This error arises because the cations that are in the soil solution are misrepresented as exchangeable. Secondly, extraction of high pH soils containing calcium carbonate (limestone) with an acid extracting agent.

There are two methods to estimate the calcium and magnesium in the soil: -

1. Using the atomic absorption.
2. Titration method.

Once a fraction of exchangeable cations has been obtained from the soil, appropriate analytical methods must be used to determine the quantity of the element. These methods for Ca^{+2} and Mg^{+2} were largely replaced by volumetric analyses based on the titration of Ca^{+2} and or Mg^{+2} by ethylenediamine tetra acetic acid disodium (EDTA).

A complex metric titration using EDTA is a classical method for determining Ca^{+2} and Mg^{+2} simultaneously or individually. Analytical success is based on eliminating possible interfering ions, achieving the required pH, and employing the appropriate indicator.

Ca^{+2} and Mg^{+2} may be titrated at pH 10 using Eriochrome Black (EBT) as an indicator. Magnesium forms insoluble $Mg(OH)_2$ at pH 12 or higher if NH_4^+ salts are absent, thereby allowing Ca^{+2} to be titrated using Concentration as an indicator. To determine Mg^{+2} alone, Ca^{+2} must first be removed by precipitation. Using tungstate to precipitate Ca^{+2} is the most common procedure. Once Ca^{+2} is removed, Mg^{+2} is titrated at pH 10 with EBT as an indicator. The procedures outlined below describe the methods for determining Ca^{+2} and Mg^{+2} either simultaneously or separately. Additional details and references have been presented by Heald (1965). However, Ca^{+2} and Mg^{+2} in the extracts can also be measured by atomic absorption spectrophotometry.

The distribution of the major exchangeable cations in productive agricultural soil is generally $Ca^{+2} > Mg^{+2} > K^+ = NH_4^+ = Na^+$ and the main two cations will be study in this experiment is Ca^{+2} and Mg^{+2}, mainly in the normal condition Ca^{+2} represented 80% of total cations in the soil and Mg^{+2} it represented about 15% of total cations in the soil, and all another cations in the soil represented the 5%, such as K^+, Na^+, Fe^{+2}, Al^{+3}.

The major sources of cations are:

1. Mineral weathering.
2. Mineralization of organic matter.
3. Soil amendments, particularly lime and fertilizer.

Presence of high concentrations of calcium, especially in the form of gypsum interferes with the determination of cation exchange capacity, which is an important parameter for soil fertility and mineralogical characterization.

Cation exchange affects many soil processes:

1. Weathering of soil minerals.
2. Nutrient absorption by plants.
3. Leaching of electrolytes.
4. Buffering of soil pH.

Equipment and materials:

Balance, Flask 200-ml, Shaker, Filter Paper, Funnel, Volumetric Flask 50-ml, Pipette, Graduated cylinder 100-ml, Burette with Magnetic Stirrer.

Reagents:

1. Ammonium acetate (CH_3COONH_4), 1N: Dissolve 77.1 g of Ammonium acetate in about 800-ml distilled water and bring to 1-L volume with distilled water.
2. Buffer solution: Dissolve 67.5 g of ammonium chloride (NH_4Cl) in 200-ml of distilled water. Add 570-ml of concentrated ammonium hydroxide (NH_4OH), and dilute the solution to a volume of 1 liter with distilled water.
3. Ethylenediaminetetraacetic acid disodium salt (EDTA) solution ≈ 0.01N: Dissolve 2 g of EDTA disodium and 0.05 g of magnesium chloride hexahydrate ($MgCl_2.6H_2O$) in distilled water, and dilute the solution to a volume of 1 liter.
4. Sodium Hydroxide Solution (NaOH), 2N Dissolve 80 g sodium hydroxide in about 800-ml distilled water, transfer the solution to a 1-L volume, cool, and bring to volume with distilled water.
5. Eriochrome Black Indicator: Dissolve 0.5 g eriochrome black with 4.5 g hydroxylamine hydrochloride in 100-ml ethyl alcohol (95%). Prepare a fresh batch every month.

Procedure:

1. Weigh 5 g air-dry soil (< 2-mm) into a 50-ml flask or centrifuge tube.
2. Add 50-ml ammonium acetate solution.
3. Shake for 1 hour on shaker.
4. Filter the solution or extraction in flask 50-ml.
5. Determine the Concentrations of Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}.

A. Calcium:

1. Pipette (10-20) ml soil saturation extract into a 250-ml Erlenmeyer flask or Beaker.
2. Dilute to 50-ml with distilled water.
3. Add 3-ml 2N sodium hydroxide solution.
4. And add a few drops eriochrome black indicator.
5. Titrate with 0.01N EDTA. The color change is from red to blue. Near the end point, EDTA should be added one drop every 10 seconds since the color change is not instantaneous.
6. Always run a blank containing all reagents but no soil, and treat it in exactly the same way as the samples; and subtract the blank titration reading from the readings for all samples.

B. Calcium plus Magnesium:

1. Pipette (10-20) ml soil saturation extract into a 250-ml Erlenmeyer flask or Beaker.
2. Dilute to 50-ml with distilled water.
3. Add 5-ml buffer solution.
4. And add a few drops eriochrome black indicator.
5. Titrate with 0.01N EDTA. The color change is from red to blue.

Data and observation sheet for calcium and magnesium determination:

Sample No.	weight of sample, g	Volume of extract, for used titration, ml	volume of EDTA titrated for sample, ml	volume of EDTA titrated for sample, ml	Ca^{2+} meq/ 100g soil	Ca^{2+} +Mg^{2+} meq/100g soil	Mg^{2+} meq/100g soil

Calculations:

$$Ca^{2+} = \left[\frac{(V - B) * N * R * 100}{Wt}\right] meq/100g \text{ soil}$$

$$Ca^{2+} + Mg^{2+} = \left[\frac{(V - B) * N * R * 100}{Wt}\right] meq/100g \text{ soil}$$

$$Mg^{2+} = \left[\left(Ca^{2+} + Mg^{2+}\right) - Ca^{2+}\right] \ meq/100g \text{ soil}$$

Where:

V = Volume of EDTA titrated for the sample (ml).
B = Blank titration volume (ml).
R = Ratio between the total volume of the extract and the extract volume used for titration.
N = Normality of EDTA solution.
Wt= Weight of air-dry soil (g).

Organic Matter

Objectives:

1. Define and understand the meaning of soil organic matter (SOM).
2. Understand the soil organic matter and what effect this has upon soil physical and biological properties.
3. Estimate soil organic matter (SOM) content of your soil using the relationship between soil color and soil organic matter content.
4. Measure SOM content of your soils using the dry combustion (loss on ignition) method.
5. Measure the organic carbon (OC) content of your soils using the modified Walkley-Black method and calculate SOM using the relationship between OC and SOM.

Introduction:

Soil organic matter (SOM) is the fraction of the soil consisting of plant and animal residues in various stages of decomposition. Organic matter contains organic carbon and nitrogen. Carbon is a source of energy and nitrogen is a source of protein for microorganisms in the soil. Some of the microorganisms are pathogens which cause plant disease but in a healthy soil the vast majorities of these organisms are beneficial and help prevent any one type of organism such as a plant pathogen from being dominant.

The amounts of soil organic matter in mineral soils vary widely across soils and vegetation cover. Mineral surface soil may contain anywhere from trace amount of SOM up to 20% by weight organic matter. On average, humid temperate regions in well drained, medium to fine texture soil have about 1-5% SOM. Even this low amount has a high influence on soil characteristics and plant growth.

SOM has a strong influence on; soil aggregation, water retention, cation exchange capacity, air/water infiltration, soil tilth, erosion reduction, efficacy of herbicide/pesticide application, solubility of plant nutrients, and overall nutrient cycling, biological activity. SOM also serves as storage for slowly released soil nutrients such as nitrogen.

Soil organic matter is extremely important with regard to soil quality. Some researchers suggest that SOM is the single most important indicator of soil quality and productivity (Larson and Pierce, 1991).

Organic carbon (OC) ranges from being the dominant constituent of peat or muck soils in colder regions of the world to being virtually absent in some desert soils. Cultivated, temperate-region soils normally have more than 3-4 % OM, while soils of semi-arid rain fed areas; have normally less than 1% OM.

Determine organic carbon levels in two ways laboratory:

1. Loss on ignition; - the soil is heated at very high temperatures and the organic matter is essentially 'burnt off'. This results in an estimation only of the organic content.
2. From organic carbon measurements;- carbon compounds are determined by involves reduction of potassium dichromate ($K_2Cr_2O_7$) by Organic Carbon compounds and subsequent determination of the unreduced dichromate by oxidation-reduction titration with ferrous sulfate (Walkley, 1947; FAO, 1974), While the actual measurement is of oxidizable organic carbon, the data are normally converted to percentage organic matter using a constant factor assuming that Organic Matter contains 58% organic carbon and then converted to soil organic matter levels using a simple calculation. This method is more accurate.

There are three basic forms of carbon in soils. They are:

1. Elemental carbon.
2. Organic carbon.
3. Inorganic carbon.

Organic Carbon may be determined by:

1. Analysis of soil for total carbon and inorganic carbon and substance of the inorganic carbon from the total.
2. A total carbon determination on the sample after destruction of inorganic carbon.
3. Reduction of $Cr_2O_7^{2-}$ by organic carbon compounds and subsequent determination of unreduced $Cr_2O_7^{2-}$ by oxidation-reduction titration with Fe^{2+} or by colorimetric techniques.

The Walkley and Black method is chosen because it is simple, rapid, widely used, and requires minimal equipment. Considered the standard method for estimating organic matter in soils. This procedure measures the easily oxidizable organic carbon (OC) by oxidation with dichromate. The reaction occurs as follows: $K_2Cr_2O_7$ is mixed with your soil and concentrated H_2SO_4 is then added.

a) $K_2Cr_2O_7 + H_2SO_4 \rightarrow H_2Cr_2O_7 + K_2SO_4 + \text{excess } H_2SO_4$

b) $3H_2Cr_2O_7+K_2SO_4+6H_2SO_4+3C\rightarrow 2Cr_2(SO_4)_3+K_2SO_4+3CO_2+8H_2O+H_2Cr_2O_7$
Orange solution green solution

The H_2SO_4 reacts with the potassium dichromate ($K_2Cr_2O_7$) to form dichromic acid (reaction a). This is a powerful oxidizing agent which oxidizes the organic carbon (also clothing and skin!), forming CO_2 and chromus sulfate (reaction b). The change in oxidation state (reduction) of chromium is accompanied by a change in color of the solution from orange to green.

The quantity of $H_2Cr_2O_7$ that was not reduced in the reaction (excess) is determined by titration with ferrous sulfate, $FeSO_4$ (reaction c), using diphenylamine as an oxidation-reduction indicator.

c) $H_2Cr_2O_7+7H_2SO_4+6FeSO_4+K_2S_4\rightarrow 3Fe_2(SO_4)_3+Cr_2(SO_4)_3+H_2SO_4+K_2SO_4+7H_2O$

Ferrous sulfate is fairly unstable and reacts with atmospheric O_2 to form ferric sulfate. Therefore, a blank solution is titrated to determine the normality of the ferrous sulfate, and this value is used in the calculations.

Soil organic matter consists of a variety of components. These include:

1. Raw plant residues and microorganisms (1 to 10 percent).
2. "Active" organic traction (10 to 40 percent).
3. Resistant organic matter also referred to as humus (40 to 60 percent).

Equipment and materials:

Balance, Spatula, Flask 500-ml or Beaker, Sieve 0.5-mm, Cylinder 100-ml, Fume hood, Filter paper, Funnel, Pipettes, Burette with Magnetic Stirrer.

Reagents:

1. Potassium Dichromate Solution ($K_2Cr_2O_7$), (1N = 1/6 M), Dissolve 49,04g potassium dichromate in distilled water, and bring to 1-L volume with distilled water.
2. Silver sulfate (Ag_2SO_4).
3. Sulfuric acid (H_2SO_4), concentrated (98 %).
4. Phosphoric acid (H_3PO_4), concentrated.
5. Ferrous sulfate Solution ($FeSO_4.7H_2O$) 0.5N: Dissolve 140g of ferrous sulfate in 800-ml distilled water and add 15-ml concentrated sulfuric acid, cool the solution, and make up to 1-L volume with distilled water.
6. Diphenylamine indicator: Dissolve 1g diphenylamine in 100-ml concentrated sulfuric acid.

Procedure:

1. Weight 1g air-dry soil (0.5 mm) into a 500-ml flask or beaker.
2. Add few granules of silver sulfate (Ag_2SO_4).
3. Add 10-ml potassium dichromate solution using a pipette.
4. Add 20-ml concentrated sulfuric acid under the fume hood, and swirl the beaker to mix the suspension.
5. Allow to stand for 30 minutes.
6. Add about 100 or 200-ml distilled water the flask.
7. Filtrate the suspension if evident that the endpoint of the titration.
8. Add 10-ml concentrated phosphoric acid, and allow the mixture to cool.
9. Add 5-10 drops diphenylamine indicator.
10. Titrate with 0.5N ferrous sulfate solution, until the color changes from violet-blue to green.
11. Prepare one blank, containing all reagents but no soil, and treat them in exactly the same way as the soil suspensions.

Data and observation sheet for organic matter determination:

Sample No.	Weight of sample, g	Volume of blank titrated with ferrous sulfate, ml	Volume of sample titrated with ferrous sulfate, ml	% Total Organic Carbon	% Organic Matter

Calculation:

$$\%\,Total\ OrganicCarbon = 0.40 * \left[\frac{\left(V_{blank} - V_{sample}\right) * N_{FeSO_4}}{Wt} \right]$$

$$\%\ Organic\ Matter = 1.724 * \%Total\ OrganicCarbon$$

Where:

N = Normality of ferrous sulfate solution. (0.5 N).

V_{Blank} = Volume of ferrous sulfate solution required to titrate the blank (ml).

V_{sample} = Volume of ferrous sulfate solution required to titrate the sample (ml).

Wt. = Weight of air-dry soil (g).

0.40 = 3 * 10^{-3} * 100, where 3 is the equivalent weight of carbon. This output from 0.3 * 1,334 and for the conversion of carbon oxidant to total organic carbon.

Vegetation types and density

Forest survey of India(FSI) has huge data on forest resources in form of thematic maps (based on interpretation of aerial photographs and on 1:50,000 scale), field inventory reports and field forms, vegetation type maps (prepared in 1981-83 on 1:2 million scale) and forest cover maps. It is envisaged to integrate these information in a single unit area (grid of appropriate size) to present the most likely forest type in a particular grid.

For this purpose the whole country is divided into a geo-referenced vector layer of' grids using Arc Info software (8.2version). The grid size of 2½′ x 2½′ which on an average encompasses 20 km^2 of area, has been chosen as the most appropriate size. In the conventional field inventory of FSI, a systematic random sampling has been used where the area is divided into grids of 2½′ x 2½′ and all the ground information is collected from the sample plots laid out in this grid. The information of thematic maps available on 1:50,000 scale can be conveniently overlaid on these grids containing 36 grids of size 2½′ x 2½′. Firstly spatial database at country level is created having vector coverage comprising 171,028 grids (Fig. 1). A unique ID is given to each grid so as attach attribute data to it. The description of the attribute data attached to each grid is as follows:

Fig. 2: Nationwide Vector Coverage of Grids of 2½′ x 2½′

i. **Forest Inventory of FSI**: Since its inception in 1965 as PISFR (Pre- Investment Survey of Forest Resources), FSI has carried out field inventory of forest resources. In addition to enumeration of trees, information on soil, species composition, density etc. of each grid in the inventory area is also available in the field forms. FSI has covered more than 80% of countries forest area under field inventory.

j. **Thematic maps prepared by FSI:** Till late nineties, FSI had been preparing thematic maps on 1:50,000 scales based on interpretation of aerial photographs. These maps in all show 48 forest land use classes and 15 non-forest land use classes. Under thematic mapping FSI has covered approximately 72% of the country's forest area. Though these maps are old but they had provided valuable base line information on species composition as usually there is no appreciable change in species composition of area over a period of time.

k. **Forest species composition maps:** For a study taken up by FSI recently, FSI had prepared forest species composition maps integrating information of thematic maps and inventory records.

l. **Vegetation type maps:** FSI prepared vegetation type maps on 1:2million scale in 1981-83. These maps were partially based on aerial photographs (thematic maps) and partially on inputs received from State Forest Departments. These maps also have provided valuable information in preparation of forest type reference maps.

m. **Latest ground truth information:** In accordance with its mandate, FSI carries out assessment of forest cover on a 2-year cycle and generates forest cover maps. These maps are based on interpretation of satellite data and extensive ground truthing is done before preparing final maps. In each cycle about 2500 points in the forest areas are visited for ground truthing. In the ground truth field forms, information on species composition is also collected

n. **Soil Maps:** Soil maps prepared by National Bureau of Soil Survey and Land Use Planning on 1:1million scale has been procured. These maps have been scanned and are being used to delineate forest types where soil composition is playing a significant role in classification of forest types.

o. **Spatial Information on Climate:** Information on temperature and rainfall on a 10’ x10’ grid size has been obtained from the Centre for Ecological Sciences, Indian Institute of Science, Bangalore. The mean annual values have been used as attribute climate data for each grid.

p. **Forest type maps prepared by other organizations:** In the year 2002, IIRS (Indian Institute of Remote Sensing) produced Biodiversity characterization maps of parts of the country like Andaman & Nicobar Islands, North Eastern region etc., Similarly, mapping work has been done by the French Institute of Pondicherry in the Western Ghats region. These maps will be used to update the reference map. Fig. 3 describes methodology of Stage 1 in brief.

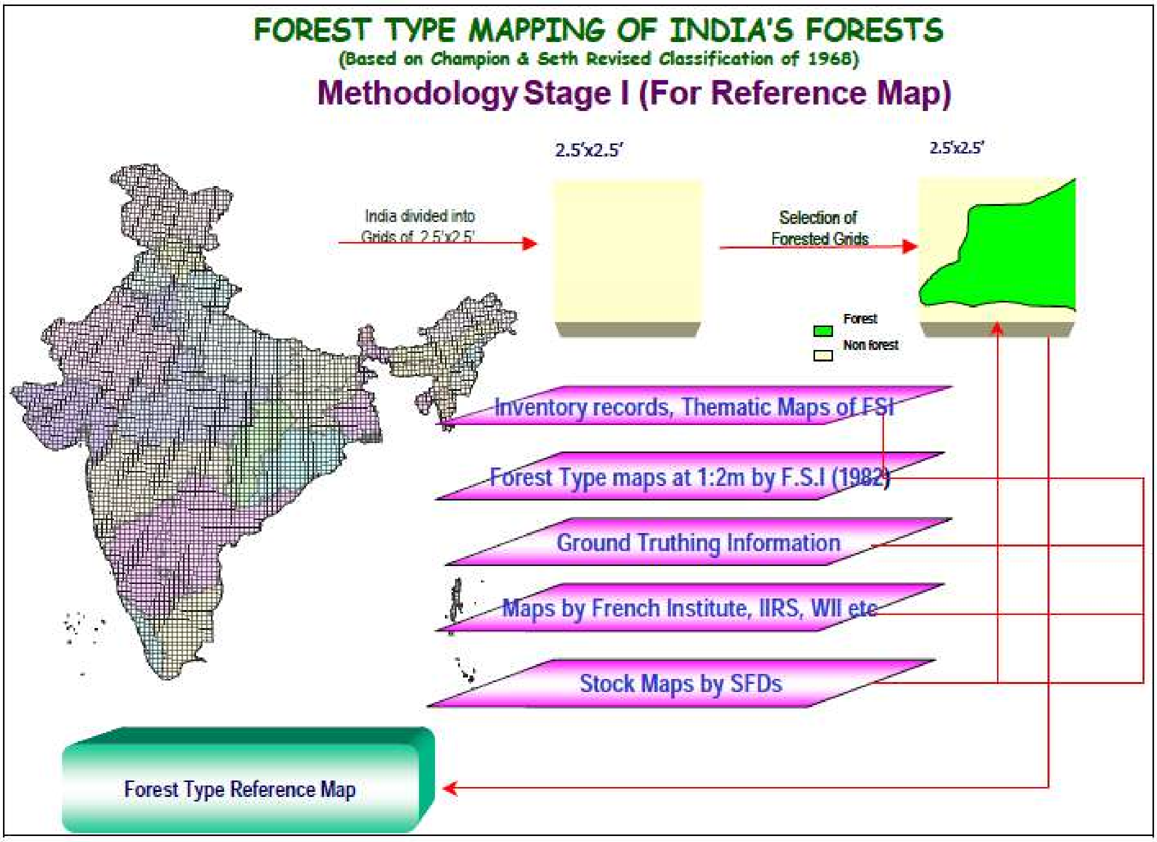


Fig-3 Methodology for Stage I for Forest Type Mapping

Preparation of final maps using new data:

The grid based forest type reference maps are being used for extensive ground verification using GPS. During ground verification, ancillary information from the State Forest Departments as available in working plans, stock maps, species composition, forest types, soil, climate, past treatment etc are also being collected. The latest satellite data of IRS 1D (LISS-III) with a spatial resolution of 23.5m X 23.5m for the year 2002 will be used for forest type classification. Multi temporal satellite data including that of dry season and high resolution data will also be used in specific cases. Digital image processing is being done using ERDAS Imagine Professional software (latest version). Following steps are being used in the digital image processing:

1. **Geometric corrections:** Images (False Colour Composites-FCC) in digital forms are first downloaded onto the computers and then registered geometrically using appropriate numbers of GCPs (Ground Control Points) of corresponding Survey of India (SOI) toposheets on 1:50,000scale. The area of interest (i.e., the District) is then extracted by overlaying digitised boundary of the district.

2. **Digital Image Processing:** FCC of the extracted area is then digitally interpreted using a hybrid approach consisting of unsupervised as well as supervised classification using maximum likelihood classifier algorithm. Ortho-rectification and NDVI (Normalized Density Vegetation Index) programmes are also run wherever needed. Rule based classification has been used in areas where topographical features and soil play dominant role in deciding forest type. The NDVI is used not only to detect spatial pattern of biodiversity but also the distribution of biophysical parameters as difference in vegetation type are primarily due to variation in soil, moisture, temperature and rainfall.

3. **Editing of Classified Forest Type Maps:** Classified forest type maps will be further edited on the basis of ground information, data on soil, climate, altitude etc Based on this post classification editing and refinement, final forest type maps will be produced on 1: 50,000 scale.

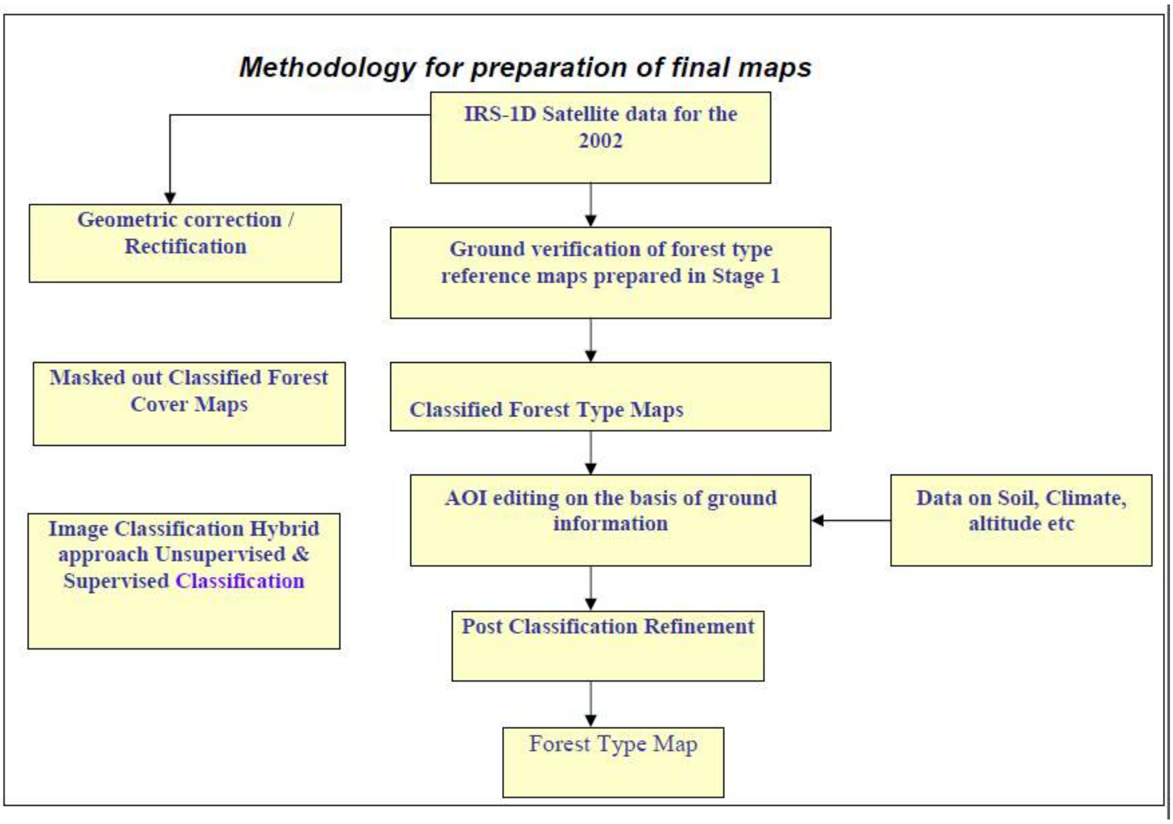


Fig 4 shows methodology of Stage 2 in brief.

Preparation of Forest Density Reference Maps:

Density in vegetation measurement refers to the number of individuals per unit area (for example plants/m^2). The term consequently refers to the closeness of individual plants to one another. The measure of density is often applied when we want to monitor changes in a given vegetation species over long periods.

Unit- GEO 196.2: PHYSICAL AND SOCIAL THEMATIC MAPPING

1. MORPHOMETRY AND DRAINAGE NETWORK ANALYSIS OF WATERSHED

Measurement of the shape or geometry of any natural form -be in plant, animal or relief features- is termed morphometry. (A.N. Strahler, 1969) but in geomorphology morphometry refers to the measurement and mathematical analysis of the configuration of the earth’s surface and its landforms. The common morphometric indices are:

i) Relative relief
ii) Dissection index
iii) Average slope
iv) Ruggedness index
v) Stream ordering
vi) Bifurcation ratio
vii) Drainage density
viii) Stream frequency

RELATIVE RELIEF:

It is defined as the difference between the highest and the lowest heights of a unit area.

PROCEDURE:

i) For convenience a small portion (10cm X 10 cm) has been selected from the topographical map. And the area has been divided into 2cm X 2cm grids.

ii) The relative relief of all the grids will be calculated by using smith’s formula:

Relative relief= highest altitude – lowest altitude

iii) Isopleths will be drawn to demarcate relative relies zones.

TABLE 1: WORKSHEET FOR RELATIVE RELIEF

CELL NO	HIGHEST ALTITUDE	LOWEST ALTITUDE	RELATIVE RELIEF (m)/km^2
A1	590	390	200
A2	605	450	155
A3	580	563	17
A4	580	535	45
A5	605	505	100
B1	550	465	85
B2	590	475	115
B3	605	535	70

B4	565	500	65
B5	595	500	95
C1	565	515	50
C2	555	515	40
C3	560	535	25
C4	565	475	90
C5	545	475	70
D1	585	425	160
D2	570	463	107
D3	565	490	75
D4	575	425	150
D5	530	425	105
E1	530	425	105
E2	550	420	130
E3	550	455	95
E4	490	410	140
E5		375	115

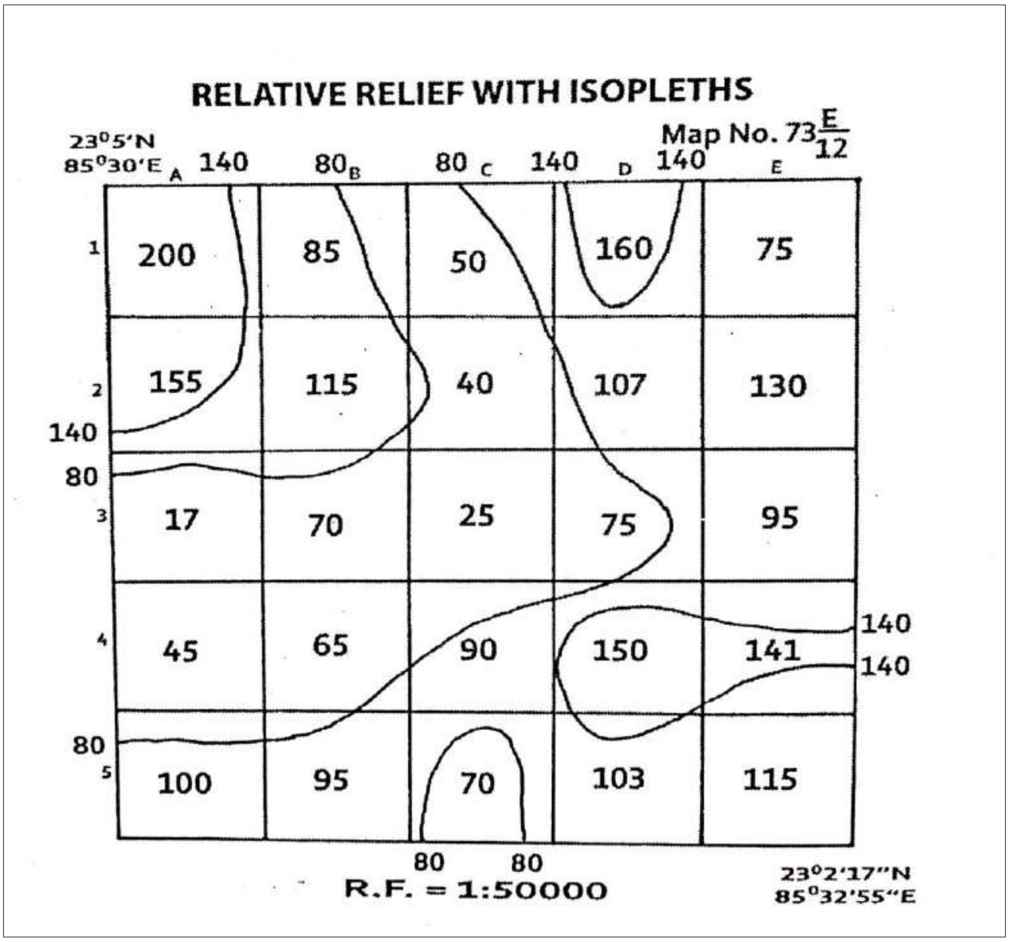


Fig 1: Relative relief

DISSECTION INDEX:

Dissection index= [(highest altitude – lowest altitude) / highest altitude]

METHODOLOGY:

i) For the calculation of D.I. the formula of Dov Nir has been followed-

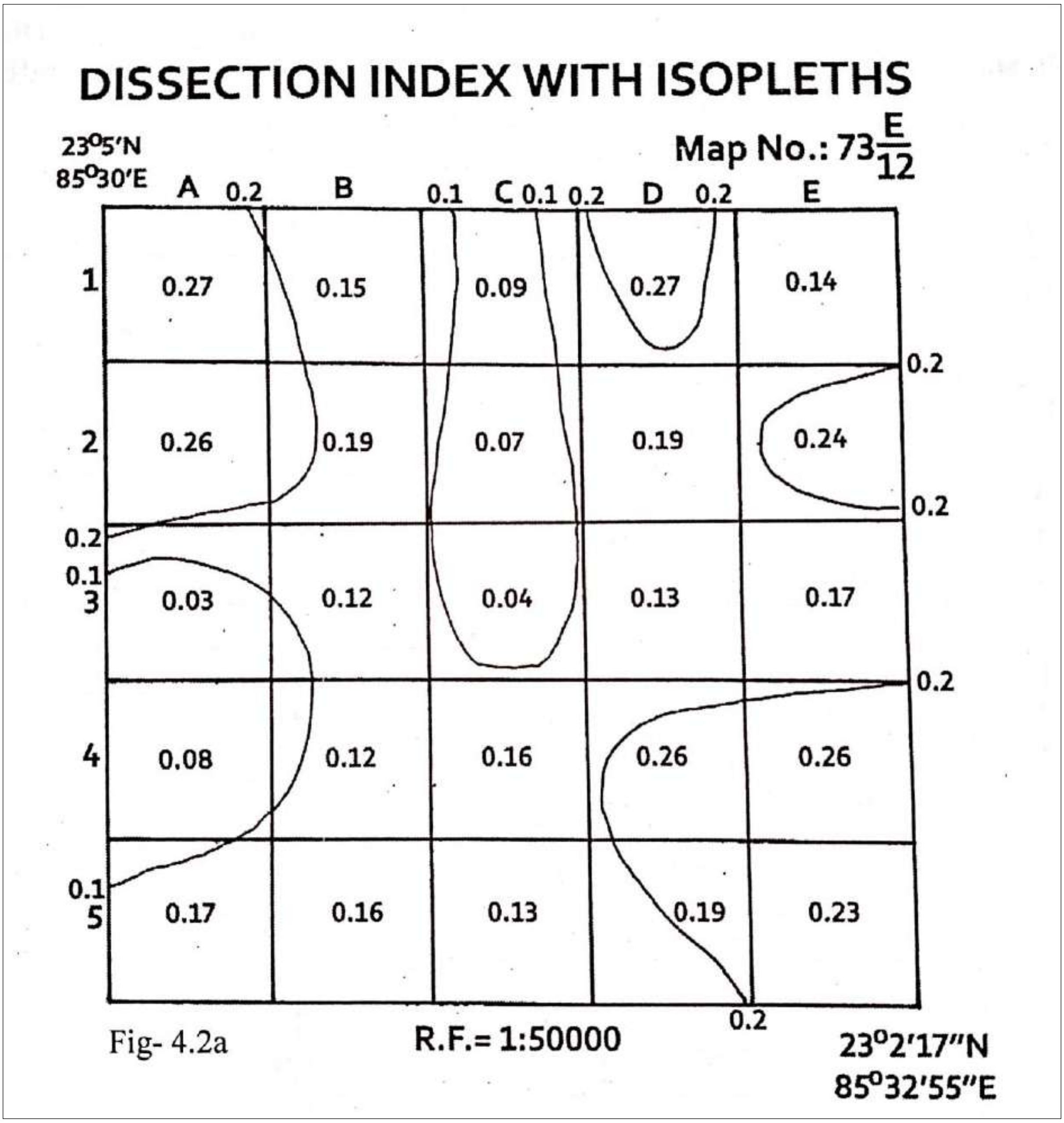
D.I. = relative relief/ absolute relief

ii) For convenience a small portion (10cm X 10 cm) has been selected from the topographical map. And the area has been divided into 2cm X 2cm grids.

iii) isopleths have been drawn for the study of spatial variation in D.I.

TABLE 2: WORKSHEET FOR DISSECTION INDEX

CELL NO	HIGHEST ALTITUDE	LOWEST ALTITUDE	RELATIVE RELIEF (m)/km^2	DISSECTION INDEX/Sq. Km
A1	590	390	200	0.34
A2	605	450	155	0.26
A3	580	563	17	0.03
A4	580	535	45	0.08
A5	605	505	100	0.17
B1	550	465	85	0.15
B2	590	475	115	0.19
B3	605	535	70	0.12
B4	565	500	65	0.12
B5	595	500	95	0.16
C1	565	515	50	0.09
C2	555	515	40	0.07
C3	560	535	25	0.04
C4	565	475	90	0.16
C5	545	475	70	0.13
D1	585	425	160	0.27
D2	570	463	107	0.19
D3	565	490	75	0.13
D4	575	425	150	0.26
D5	530	425	105	0.20
E1	530	425	105	0.16
E2	550	420	130	0.24
E3	550	455	95	0.17
E4	490	410	140	0.25
E5		375	115	0.23



	A	B	C	D	E
1	0.27	0.15	0.09	0.27	0.14
2	0.26	0.19	0.07	0.19	0.24
3	0.03	0.12	0.04	0.13	0.17
4	0.08	0.12	0.16	0.26	0.26
5	0.17	0.16	0.13	0.19	0.23

Fig 2: Dissection index

AVERAGE SLOPE:

Slope is the angular inclination of terrain. The most widely used formula for determination of average slope is –

$$\text{Average slope}^{\theta} = \tan^{-1} N X 1/K$$

Where,

N= average number of contours crossing per km or mile

I= contour interval

K = constant (636.6 for km map, 3361 for mile map)

PROCEDURE:

i) For convenience a small portion (10cm X 10 cm) has been selected from the topographical map. And the area has been divided into 2cm X 2cm grids.

ii) Apply Wentworth formula to determine the average slope of all grids.

iii) Isopleths have been drawn to show the spatial variation in average slope.

TABLE 3: WORKSHEET FOR AVERAGE SLOPE

CELL NO	AVG. NO OF CONTOUR CROSSING	CONTOUR INTERVAL	CONSTANT (K)	SLOPE$^{\theta}$
A1	10	20	636.6	17°26' 27“
A2	95	20	636.6	15° 47' 18
A3	8.25	20	636.6	8° 55' 38"
A4	7.75	20	636.6	14° 31' 50”
A5	5	20	636.6	13° 41'3"
B1	6.75	20	636.6	8° 55'38”
B2	6	20	636.6	11° 58'22“
B3	5.75	20	636.6	10^{0}40'33”
B4	2	20	636.6	*10*° 14'23”
B5	3.75	20	636.6	3° 35'43"
C1	4.5	20	636.6	6° 43'9“
C2	6	20	636.6	8° 2'48"
C3	3.50	20	636.6	10° 40' 30"
C4	1.75	20	636.6	6° 16' 29"
C5	1.7	20	636.6	3º8’48’’
D1	5	20	636.6	2° 41' 53"
D2	4.5	20	636.6	12^{o} 24' 10”
D3	1	20	636.6	8° 2' 48"
D4	0.75	20	636.6	1° 47'58"
D5	3.50	20	636.6	1° 20'59”
E1	8.25	20	636.6	6° 16'29”
E2	2.75	20	636.6	14º31'29”
E3	0.5	20	636.6	4º16'29”
E4	0.5	20	636.6	0º53'29”
E5	0	20	636.6	0

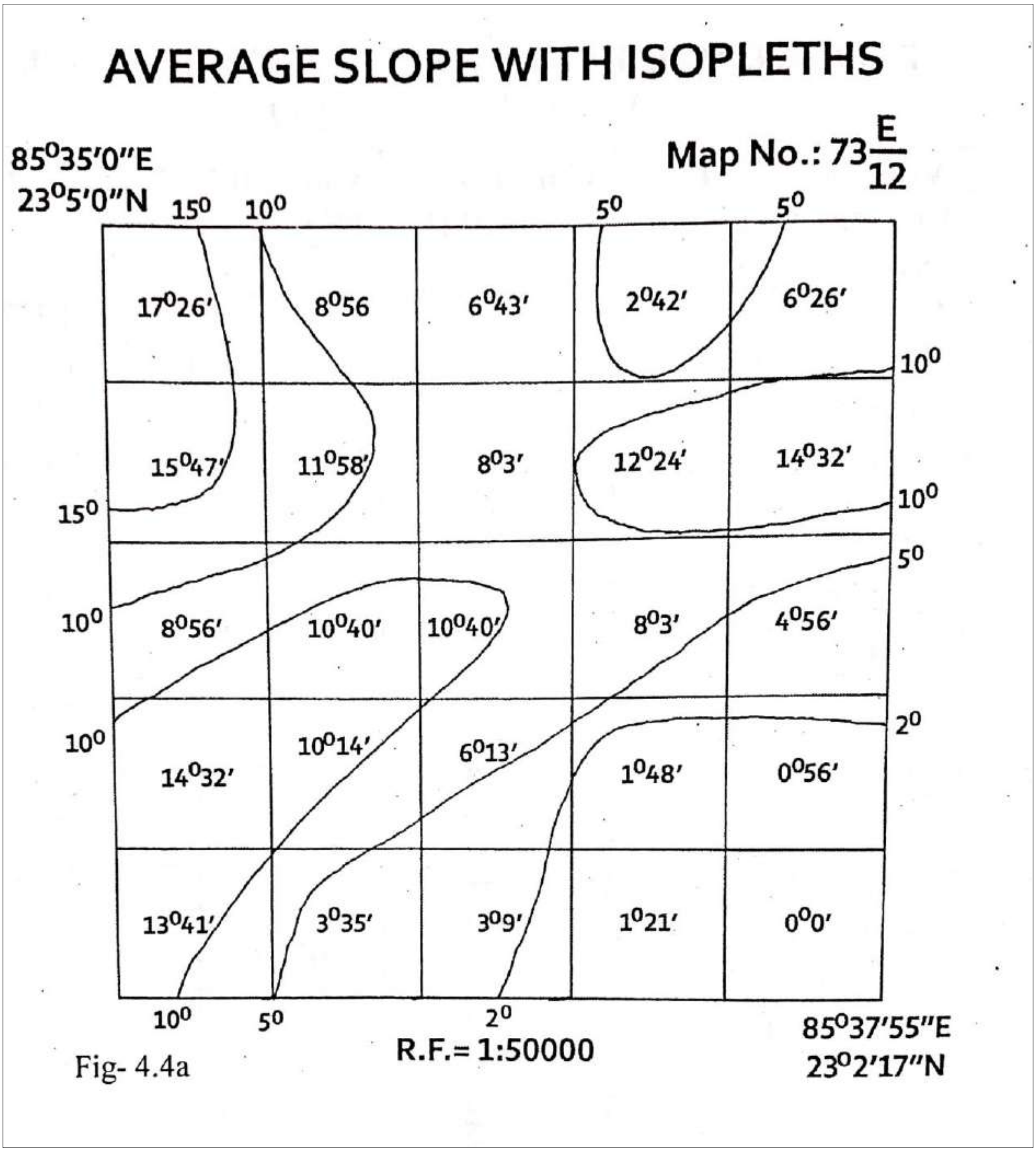


Fig 3: average slope map

RUGGEDNESS INDEX:

It is the measure of surface unevenness. The formula for determination of R.I is

R.I. = relative relief x drainage density/ k (constant)

K = 5280 for mile map, 1000 for km map.

TABLE 4: WORKSHEET FOR RUGGEDNESS INDEX

CELL NO	HIGHEST ALTITUDE	LOWEST ALTITUDE	RELATIVE RELIEF (m)/km^2	Channel length		Area (km^2)	D.D (km/ Km$^{2)}$	R.I
				In cm	In km			
A1	590	390	200	6	3	1	3	0.24
A2	605	450	155	5	2.5	1	2.5	0.3
A3	580	563	17	4	2	1	2	0.16
A4	580	535	45	6	3	1	3	0.48
A5	605	505	100	2.2	1.1	1	1.1	0.18
B1	550	465	85	6	3	1	3	0.54
B2	590	475	115	5.8	2.9	1	2.9	0.52
B3	605	535	70	5.2	2.6	1	2.6	0.21
B4	565	500	65	6.4	3.2	1	3.2	0.38
B5	595	500	95	5	2.5	1	2.5	0.10
C1	565	515	50	5.2	2.6	1	2.6	0.29
C2	555	515	40	6.6	3.3	1	3.3	0.23
C3	560	535	25	3.4	1.7	1	1.7	0.19
C4	565	475	90	6	3	1	3	0.06
C5	545	475	70	3.4	1.7	1	1.7	0.05
D1	585	425	160	5.4	2.7	1	2.7	0.08
D2	570	463	107	4	2	1	2	0.35
D3	565	490	75	3.2	1.6	1	1.6	0.23
D4	575	425	150	1	0.5	1	0.5	0.02
D5	530	425	105	2.8	1.4	1	1.4	0.03
E1	530	425	105	5.2	2.6	1	2.6	0.18
E2	550	420	130	3.2	1.6	1	1.6	0.19
E3	550	455	95	4.2	2.1	1	2.1	0.20
E4	490	410	140	4	2	1	2	0.04
E5		375	115	0	0	1	0	0.00

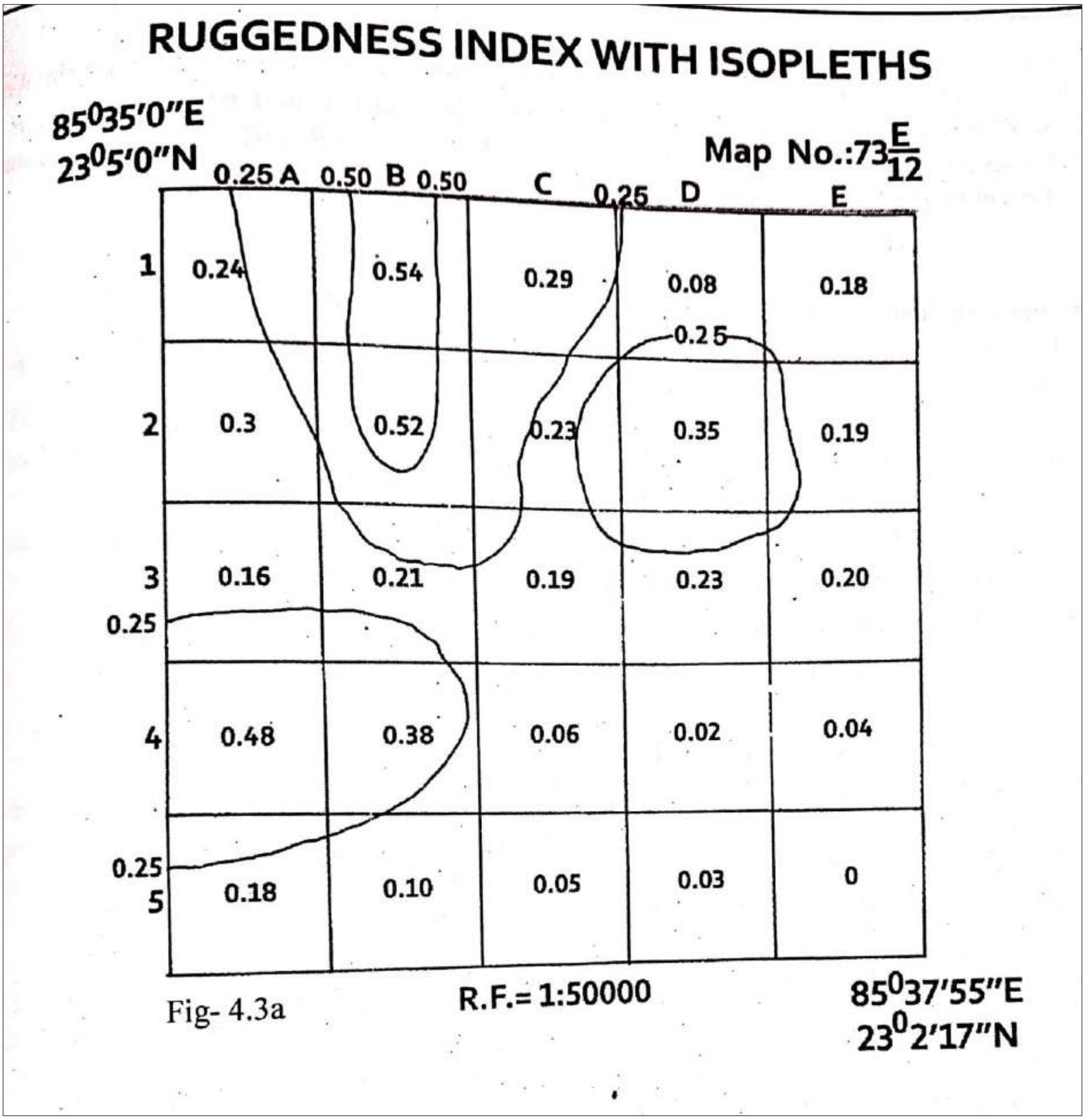


Fig 4: Ruggedness index map

DRAINAGE DENSITY:

It refers to total stream length per unit area. R.E. Horton (1945) defined drainage density as a ratio of total length of all stream segments in a given drainage basin to the total area of that basin and thus the formula to derive drainage density is-

Drainage density = total length of all segments of unit area/ area of the basin

PROCEDURE:

i) For convenience a small portion (10cm X 10 cm) has been selected from the topographical map. And the area has been divided into 2cm X 2cm grids.

ii) The stream length of all unit areas has been measured and the D.D is derived.

iii) For the study of spatial variation in D.D the isopleths have been drawn.

iv)

TABLE 5: WORKSHEET FOR DRAINAGE DENSITY

CELL NO	Channel length		Area (km^2)	D.D (km/ $Km^{2)}$
	In cm	In km		
A1	6	3	1	3
A2	5	2.5	1	2.5
A3	4	2	1	2
A4	6	3	1	3
A5	2.2	1.1	1	1.1
B1	6	3	1	3
B2	5.8	2.9	1	2.9
B3	5.2	2.6	1	2.6
B4	6.4	3.2	1	3.2
B5	5	2.5	1	2.5
C1	5.2	2.6	1	2.6
C2	6.6	3.3	1	3.3
C3	3.4	1.7	1	1.7
C4	6	3	1	3
C5	3.4	1.7	1	1.7
D1	5.4	2.7	1	2.7
D2	4	2	1	2
D3	3.2	1.6	1	1.6
D4	1	0.5	1	0.5
D5	2.8	1.4	1	1.4
E1	5.2	2.6	1	2.6
E2	3.2	1.6	1	1.6
E3	4.2	2.1	1	2.1
E4	4	2	1	2
E5	0	0	1	0

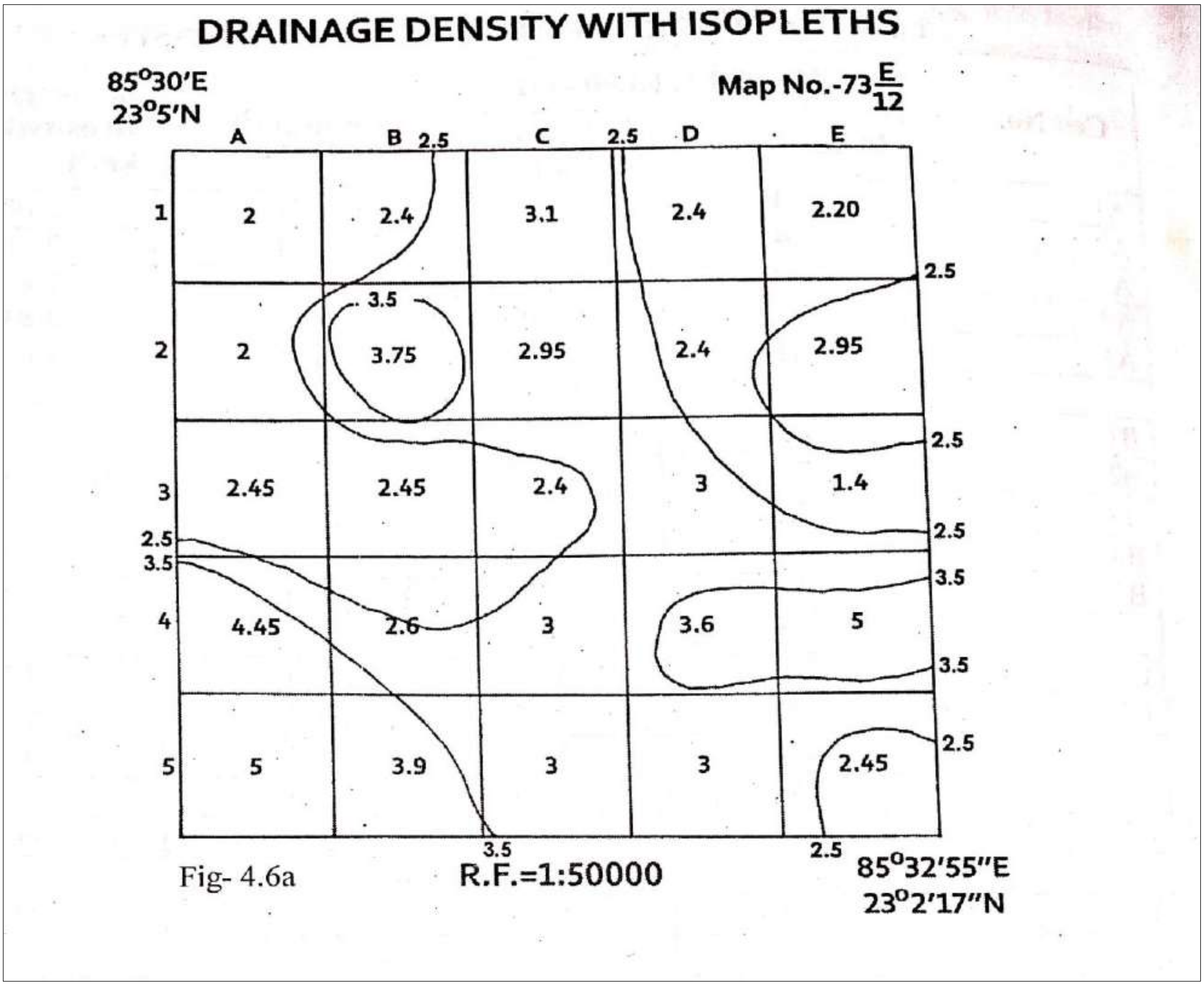


Fig 5: Drainage density map

STREAM ORDERING:

Stream order is a measure of the position of a stream in the hierarchy of tributaries. The main aim of stream ordering is to determine the hierarchy of a stream within a drainage basin.

PROCEDURE:

Stream ordering by HORTON:

According to Horton ordering of stream begins from the fingertip tributaries, which don not have their own feeders. They are designated as 1st order stream

Two stream of 1st order join together to form 2nd order stream.

Two streams of 2nd order join together to form 3rd order stream.

Stream ordering by STRAHLER:

Each fingertip channel is designated as a segment of 1st order.

At the junction of any two 1st order segments, a channel of 2nd order is produced.

It extends to the point where it joins another 2nd order segment where upon a segment of 3rd order results and so forth.

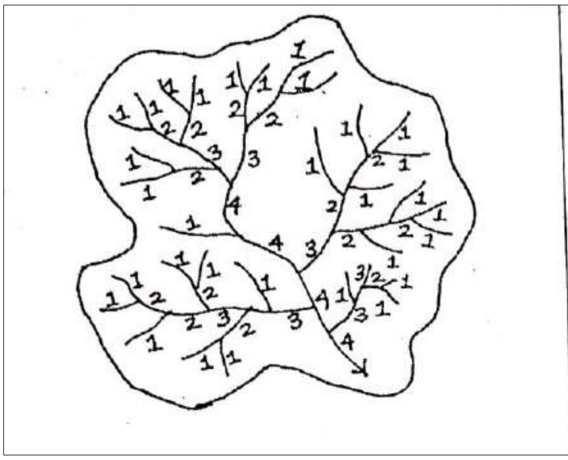


Fig 6: stream ordering after Strahler

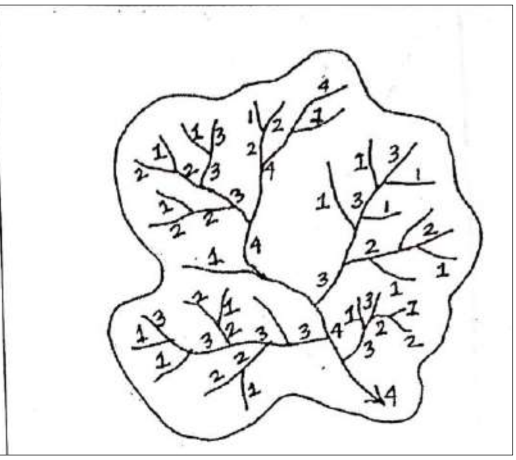


Fig 7: stream ordering after Horton

BIFURCATION RATIO:

Robert h. Horton introduced the term bifurcation ratio to express the ratio of the number of streams of any given order to the number in the next higher order. It is expressed by the following equation-

Bifurcation ratio = number of streams in a given order/ number of streams of the next higher order.

TABLE 6: CALCULATION OF BIFURCATION RATIO

STREAM ORDER	NO. OF STREAMS	BIFURCATION RATIO
1	7	-
2	2	3.5
3	1	2

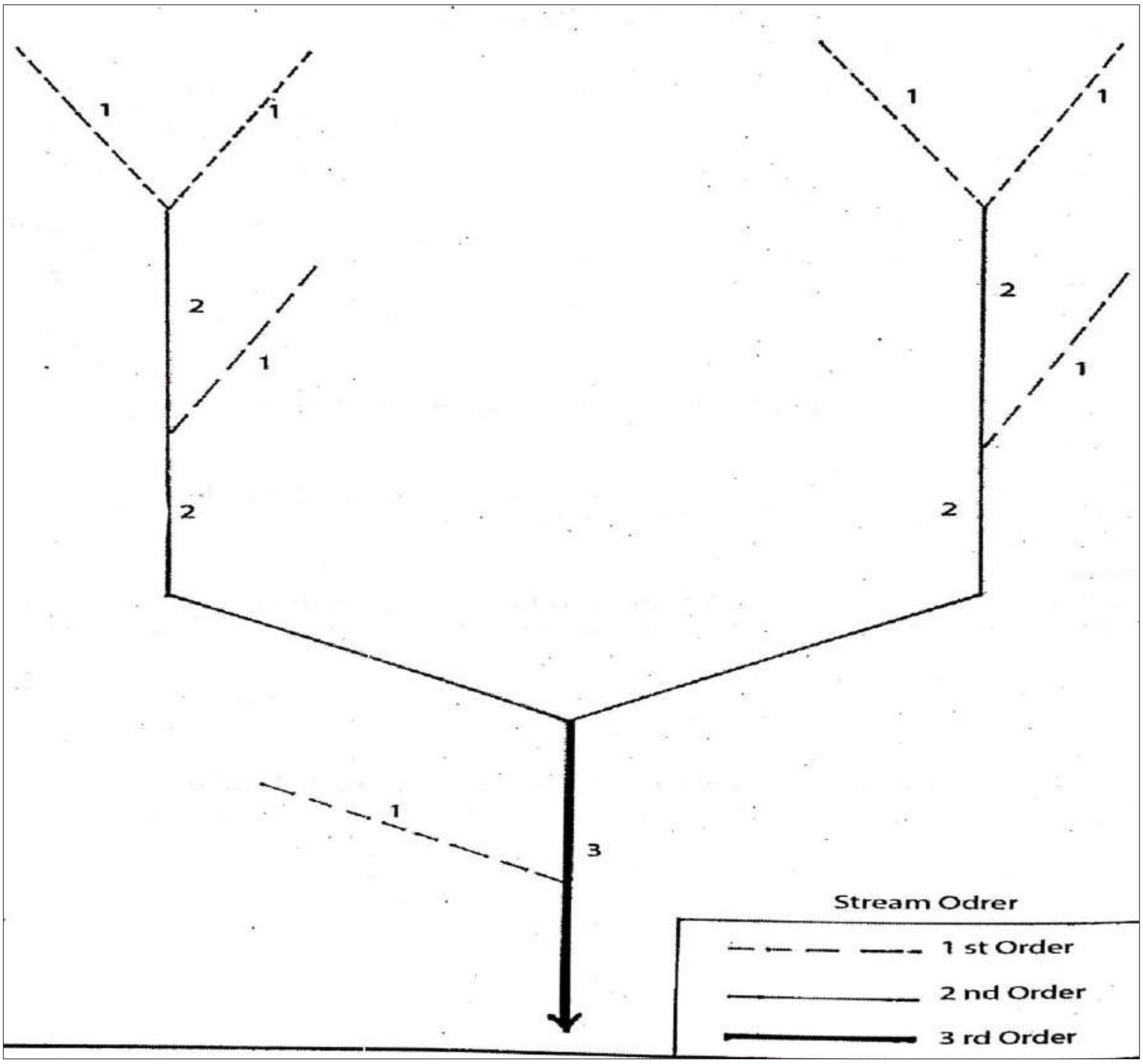


Fig 8: Stream ordering after Strahler

STREAM FREQUENCY:

It is the measurement of the number of streams per unit area. So, the formula is-

Stream frequency = no. of streams/ area in sq. km/mile

TABLE 7: WORKSHEET FOR STREAM FREQUENCY

CELL NO	NO. OF STREAMS	AREA IN SQ. KM	STREAM FREQUENCY/ KM^2
A1	10	1	10
A2	7	1	7
A3	6	1	6
A4	7	1	7
A5	5	1	5
B1	9	1	9

B2	6	1	6
B3	9	1	9
B4	9	1	9
B5	6	1	6
C1	5	1	5
C2	8	1	8
C3	6	1	6
C4	8	1	8
C5	5	1	5
D1	8	1	8
D2	10	1	10
D3	3	1	3
D4	1	1	1
D5	3	1	3
E1	7	1	7
E2	4	1	4
E3	3	1	3
E4	2	1	2
E5	1	1	1

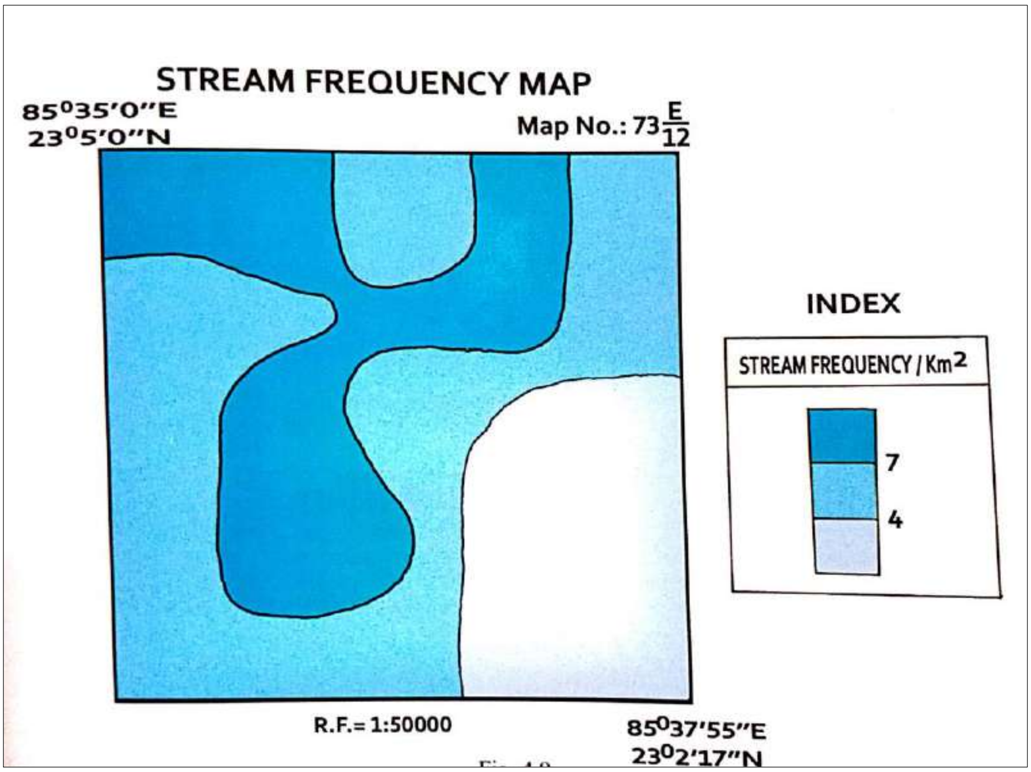


Fig. 9:

2. MAPPING OF FARMING PRACTICES: CROP-COMBINATION, DIVERSIFICATION AND CROPPING INTENSITY

CROP-COMBINATION:

The study of crop combination regions constitutes an important aspect of agricultural geography as it provides a good basis for agricultural regionalization. For a comprehensive and clear understanding of the agricultural mosaic of an agro-climatic region and for the planning and development of its agriculture, a systematic study of crop combinations is of great significance.

PROCEDURE:

Step 1: First we need to collect total harvested crop land data from secondary sources.

Step 2: then we will apply the formula for calculating crop combination using weaver’s method or Rafiullah’s method.

Step 3:

WEAVER’S METHOD:

In the field of agricultural geography Weaver (1954) was the first to use statistical technique to establish the crop combination of the Middle West (USA).

Monoculture = 100 per cent of the total harvested crop land in one crop.

2- Crop combination = 50 per cent in each of two crops.

3- Crop combination = 33.3 per cent in each of three crops.

4- Crop combination = 25 per cent in each of four crops.

5- Crop combination = 20 per cent in each of live crops.

10-crop combination = 10 per cent in each of 10 crops.

$$d = \frac{\Sigma d^2}{n}$$

To illustrate the Weaver’s technique an illustration can be given from Gorakhpur district in which the percentage share of crops in the cropped area in a year was as follows: rice 48 per cent, wheat 23 per cent, barley 15 per cent, sugarcane 6 per cent, and gram 5 per cent.

Monoculture

$$= \frac{(100-48)^2}{1} = 2704$$

2-crop combination

$$= \frac{(50-48)^2 + (50-23)^2}{2} = 366.5$$

3-crop combination

$$= \frac{(33.3-48)^2 + (33.3-23)^2 + (33.3-15)^2}{3} = 216$$

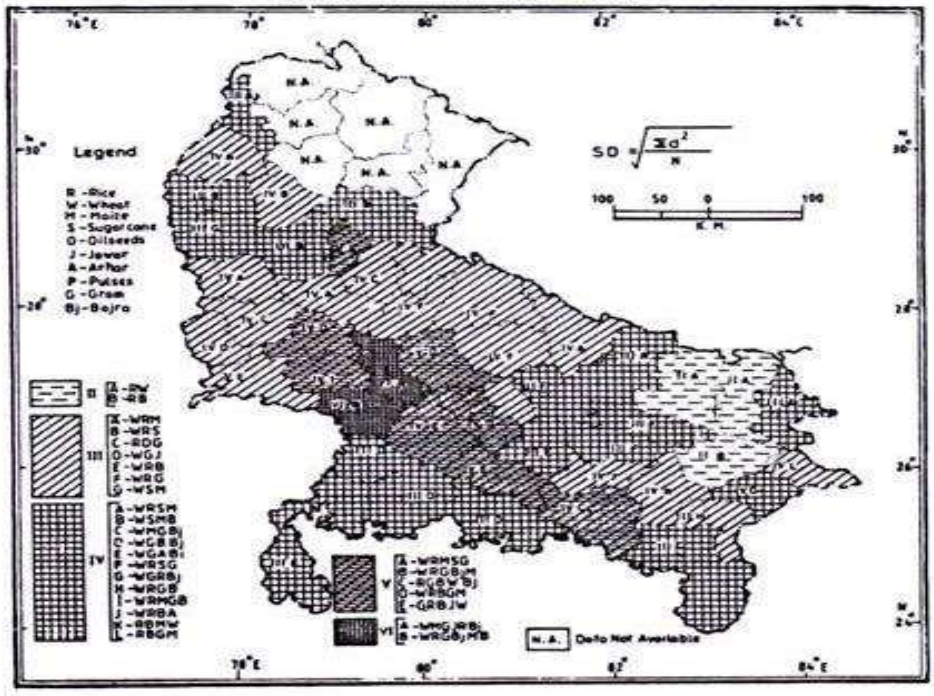
4-crop combination

$$= \frac{(25-48)^2 + (25-23)^2 + (25-15)^2 + (25-6)^2}{4} = 248$$

5-crop combination

$$= \frac{(20-48)^2 + (20-23)^2 + (20-15)^2 + (20-6)^2 + (20-5)^2}{5} = 248$$

The deviation of the actual percentages from the theoretical curve is seen to be the lowest for a 3-crop combination. This result established the identity and the number of crops in the basic combination for the district as RWB (rice-wheat-barley).



Uttar Pradesh: Crop Combination Regions, 1991-94
(Standard Deviation Method)

RAFIULLAH'S METHOD:

Looking at the inherent weakness of Weaver's method which tends to include all or most of the crops in the series by which the resultant combination become over generalized, Rafiullah (1956) developed a new deviation method in his work New Approach to the Functional Classification of Towns.

The technique devised by Rafiullah may be expressed as follows:

$$d = \sqrt{\frac{\Sigma D_p^2 - D_n^2}{N^2}}$$

Where, d is the deviation, D_p is the positive difference and D_n is the negative difference from the median value of the theoretical curve value of the combination, and N is the number of functions (crops) in the combination.

To illustrate Rafiullah's maximum positive deviation method an illustration can be given from the Basti district of Uttar Pradesh, in which rice occupies 54 per cent, wheat 23 per cent, barley 9 per cent and sugarcane 5 per cent of the total c.

$$\text{Monoculture} = \frac{(54-50)^2}{N^2} = \frac{(4)^2}{(1)^2} = 16$$

$$\text{2-crop combination} = \frac{(54-25)^2 - (23-25)^2}{N^2} = 209.25$$

3-crop combination =

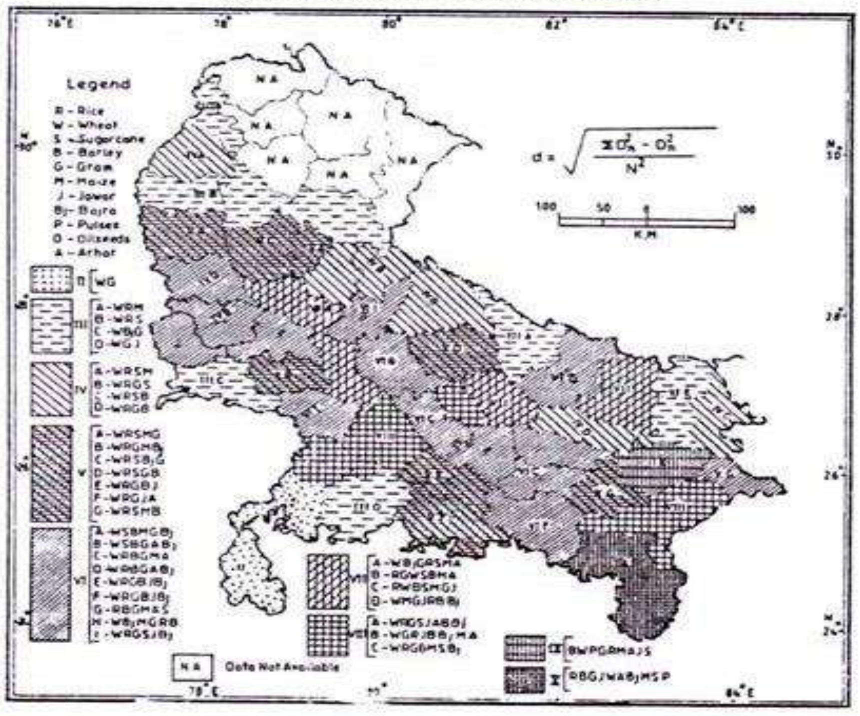
$$\frac{(54-16.7)^2 + (23-16.7)^2 - (9-16.7)^2}{N^2} = 140.18$$

4- crop combination =

$$\frac{(54-12.5)^2 + (23-12.5)^2 - (9-12.5)^2 - (5-12.5)^2}{N^2} = 109.12$$

Since the variance of the 2-crop combination (209.25) is the maximum positive deviation, the district is designated with the 2- crop combination, i.e., rice and wheat (RW).

In the maximum positive deviation method, unlike the standard deviation method, the differences of actual values are calculated from the middle value of the theoretical standard and thus this method also gives the desired critical combination. An application of the maximum positive deviation method to the agricultural data of Uttar Pradesh results in the recognition of 6-crop combination. The combinations are mapped in the following Figure:



Uttar Pradesh: Crop Combination Regions, 1991-94
(Maximum Positive Deviation Method)

$$d = \sqrt{\frac{\Sigma D_n^2 - O_n^2}{N^2}}$$

CROP DIVERSIFICATION:

Crop diversification refers to the raising of varieties of crops in a given area in a crop season. The more is the number of crops grown in an area, the higher is the crop diversification.

PROCEDURE:

Step 1: Data related to total crop area need to be collected from secondary sources.

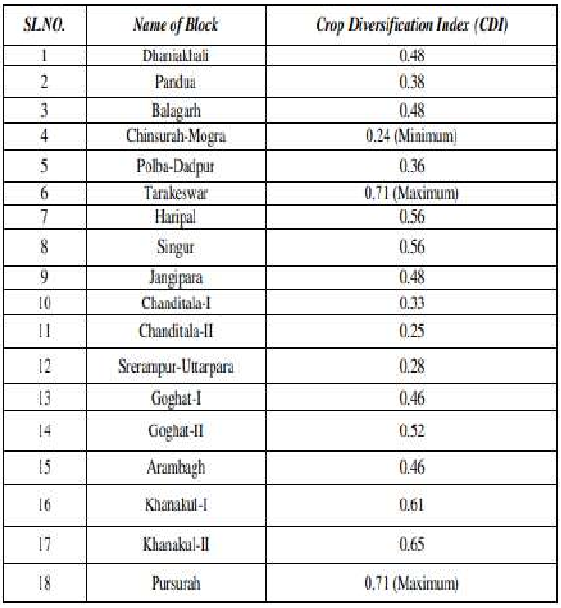
Step 2: By applying Gibb's and martin formula crop diversification index will be calculated.

Step 3: range will be selected and no of blocks falling under each category need to be demarcated.

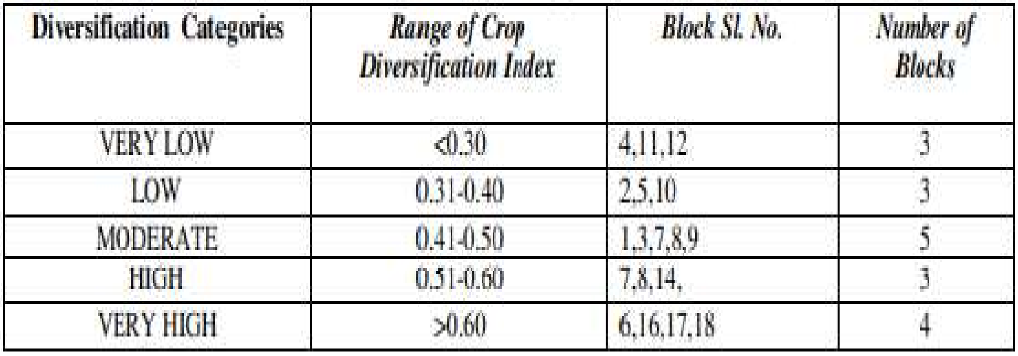
GIBB'S & MARTIN FORMULA:

Crop Diversification Index (CDI) = $1- \{\Sigma X^2 / (\Sigma X)^2\}$

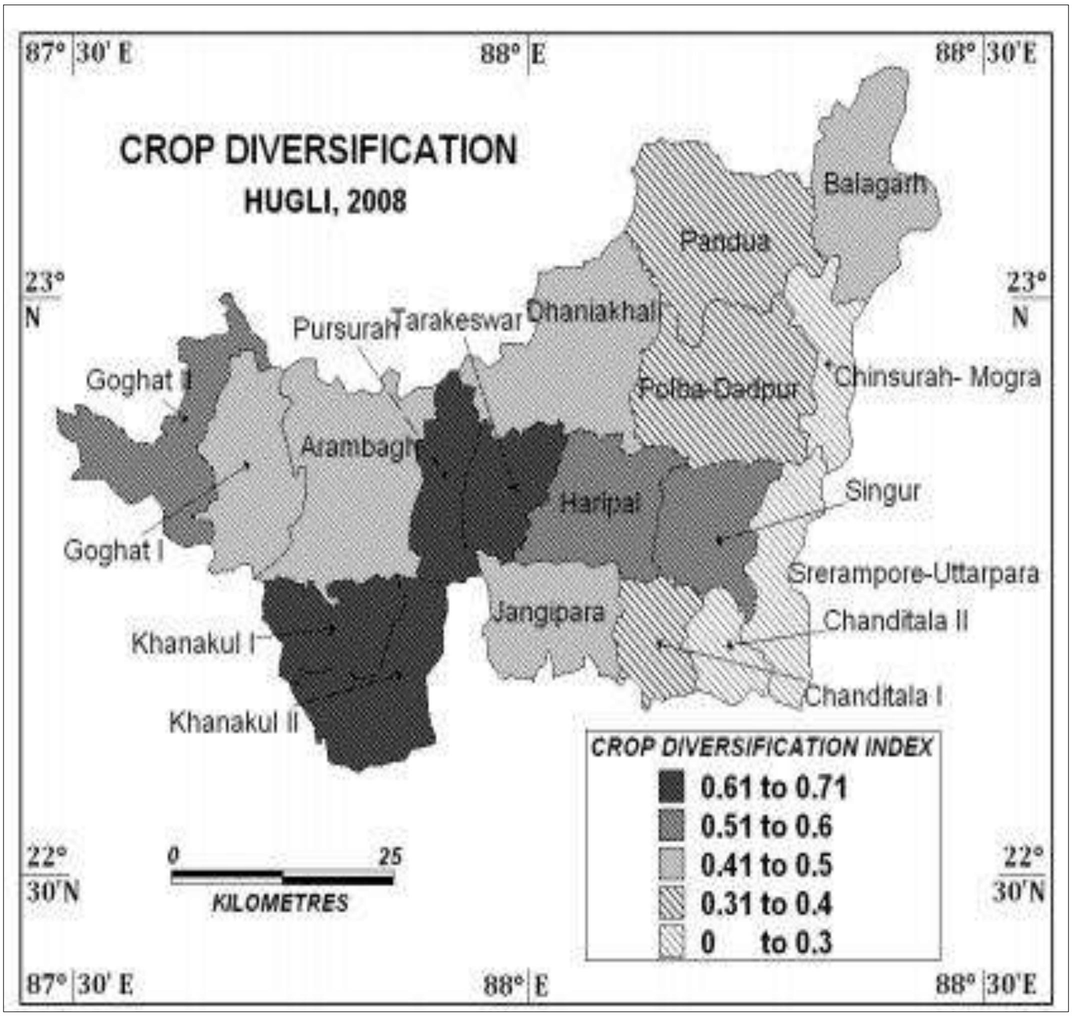
Where, X is the percentages of the total cropped area occupied by each crop or hectare under individual crop. If the total cultivated area in a region is devoted wholly to one crop (i.e., specialization) the index value will be zero (0) and if it is evenly distributed among all crops (i.e., maximum diversification) the index value approaches one (1).



SL.NO.	Name of Block	Crop Diversification Index (CDI)
1	Dhaniakhali	0.48
2	Pandua	0.38
3	Balagarh	0.48
4	Chinsurah-Mogra	0.24 (Minimum)
5	Polba-Dadpur	0.36
6	Tarakeswar	0.71 (Maximum)
7	Haripal	0.56
8	Singur	0.56
9	Jangipara	0.48
10	Chanditala-I	0.33
11	Chanditala-II	0.25
12	Srerampur-Uttarpara	0.28
13	Goghat-I	0.46
14	Goghat-II	0.52
15	Arambagh	0.46
16	Khanakul-I	0.61
17	Khanakul-II	0.65
18	Pursurah	0.71 (Maximum)



Diversification Categories	*Range of Crop Diversification Index*	*Block Sl. No.*	*Number of Blocks*
VERY LOW	<0.30	4,11,12	3
LOW	0.31-0.40	2,5,10	3
MODERATE	0.41-0.50	1,3,7,8,9	5
HIGH	0.51-0.60	7,8,14,	3
VERY HIGH	>0.60	6,16,17,18	4



CROPPING INTENSITY:

It is the ratio of Net Area Sown to the Total Cropped Area.

Net Area Sown: This represents the total area sown with crops and orchards. Area sown more than once in the same year is counted only once.

Gross Cropped Area: This represents the total area sown once and/or more than once in a particular year, i.e. the area is counted as many times as there are sowings in a year. This total area is also known as total cropped area or total area sown.

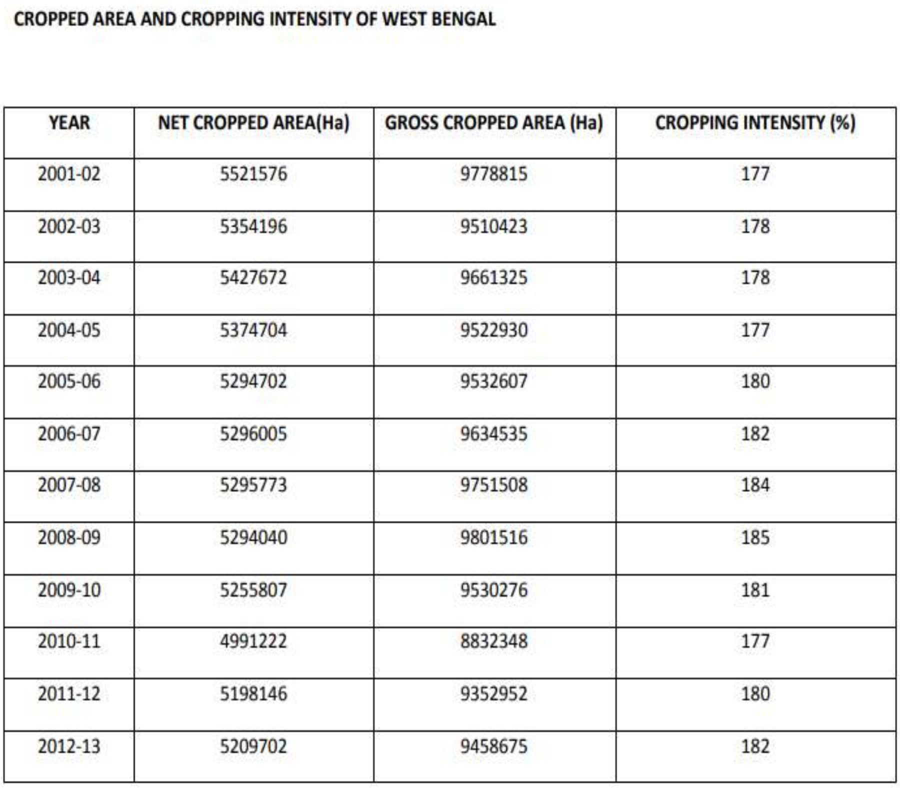
PROCEDURE:

STEP 1: Data related to total area sown needs to be collected first.

STEP 2: Then by applying the crop intensity formula cropping intensity will be calculated.

FORMULA:

$$CI = \frac{\text{Gross cropped area}}{\text{Net area sown}}$$



CROPPED AREA AND CROPPING INTENSITY OF WEST BENGAL

YEAR	NET CROPPED AREA(Ha)	GROSS CROPPED AREA (Ha)	CROPPING INTENSITY (%)
2001-02	5521576	9778815	177
2002-03	5354196	9510423	178
2003-04	5427672	9661325	178
2004-05	5374704	9522930	177
2005-06	5294702	9532607	180
2006-07	5296005	9634535	182
2007-08	5295773	9751508	184
2008-09	5294040	9801516	185
2009-10	5255807	9530276	181
2010-11	4991222	8832348	177
2011-12	5198146	9352952	180
2012-13	5209702	9458675	182

3. MAPPING OF SOCIAL VULNERABILITY AND SOCIAL DISPARITIES, ETHNIC MAPPING.

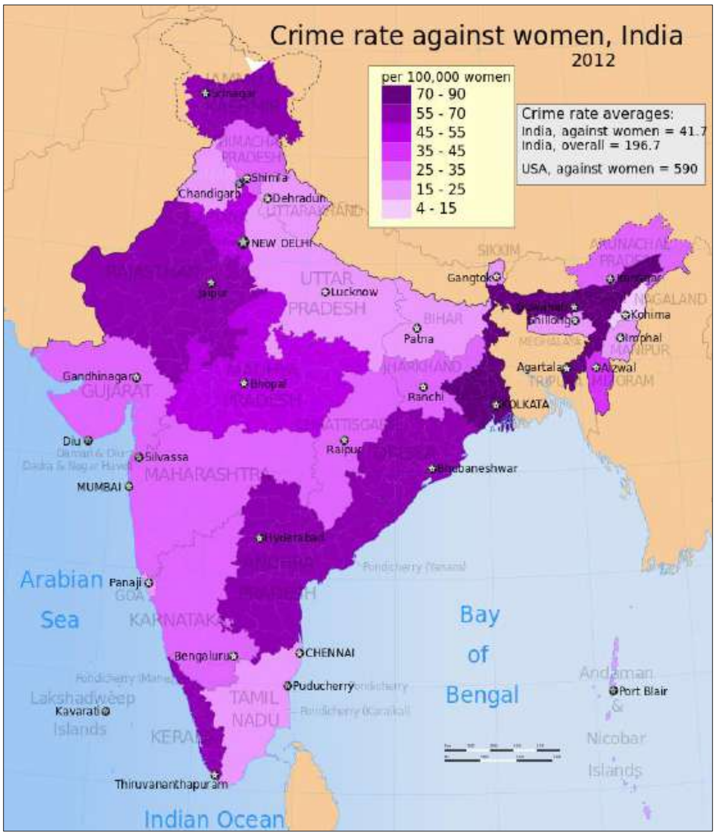
SOCIAL VULNERABILITY:

Social vulnerability refers to the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed. These impacts are due in part to characteristics inherent in social interactions, institutions, and systems of cultural values.

PROCEDURE:

STEP 1: First data related to social vulnerability needs to be collected from secondary sources. Here data on crime rate against women has been used.

STEP 2: The data will then be categorized into different classes and a choropleth map will be prepared on the basis of the obtained data.



MAP 3.1: CRIME RATE AGAINST WOMEN OF INDIA

ETHNIC MAPPING:

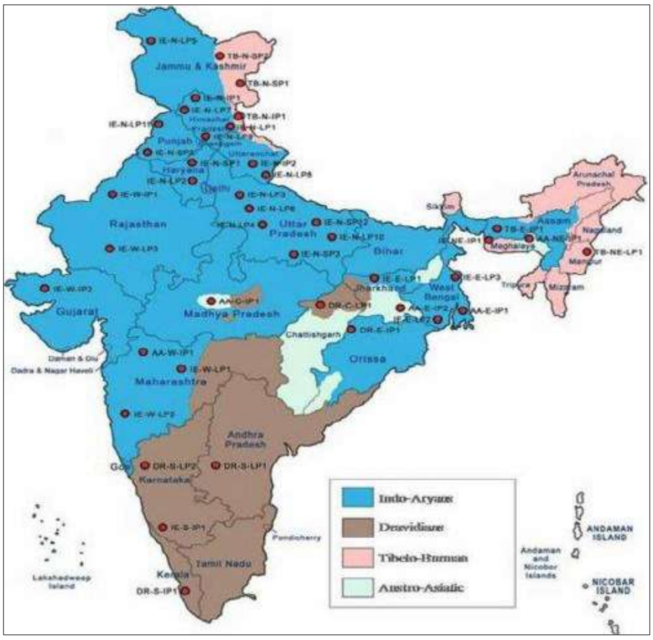
An **ethnic group** or **ethnicity** is a grouping of humans based on people who identify with each other on the basis of shared attributes that distinguish them from other groups such as a common set of traditions, ancestry, language, history, society, culture, nation, religion, or social treatment within their residing area.

In ethnic mapping we prepare maps showing distribution of different components of ethnicity.

PROCEDURE:

STEP 1: To prepare ethnicity map we need to collect data on ethnicity from secondary sources. Here data related to different ethnic groups has been used.

STEP 2: A chorochromatic map will be prepared using different colours to indicate ethnic groups.



MAP 3.2 ETHNIC GROUPS OF INDIA

4. ESTIMATION AND MAPPING OF SOCIAL WELL BEING:

The Human Development Index (HDI) is an index that measures key dimensions of human development. The three key dimensions are:

– A long and healthy life – measured by life expectancy.

– Access to education – measured by expected years of schooling of children at school-entry age and mean years of schooling of the adult population.

– And a decent standard of living – measured by Gross National Income per capita adjusted for the price level of the country.

PROCEDURE:

STEP 1: To construct the Index, fixed minimum and maximum values have been established for each of the indicators:

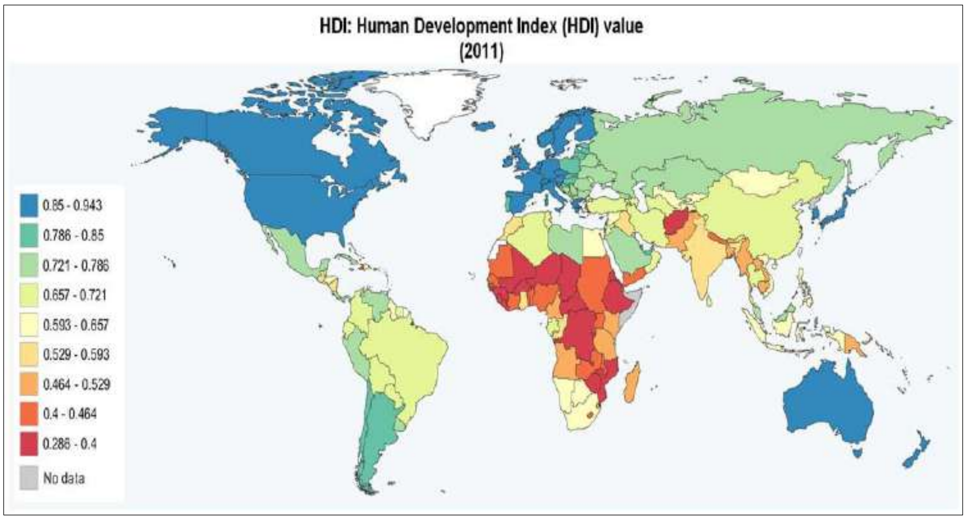
i. Life expectancy at birth: 25 years and 85 years;

ii. General literacy rate: 0 per cent and 100 per cent;

ii. Real GDP per capita (PPP$); PPP$ 100 and PPP$ 40,000.

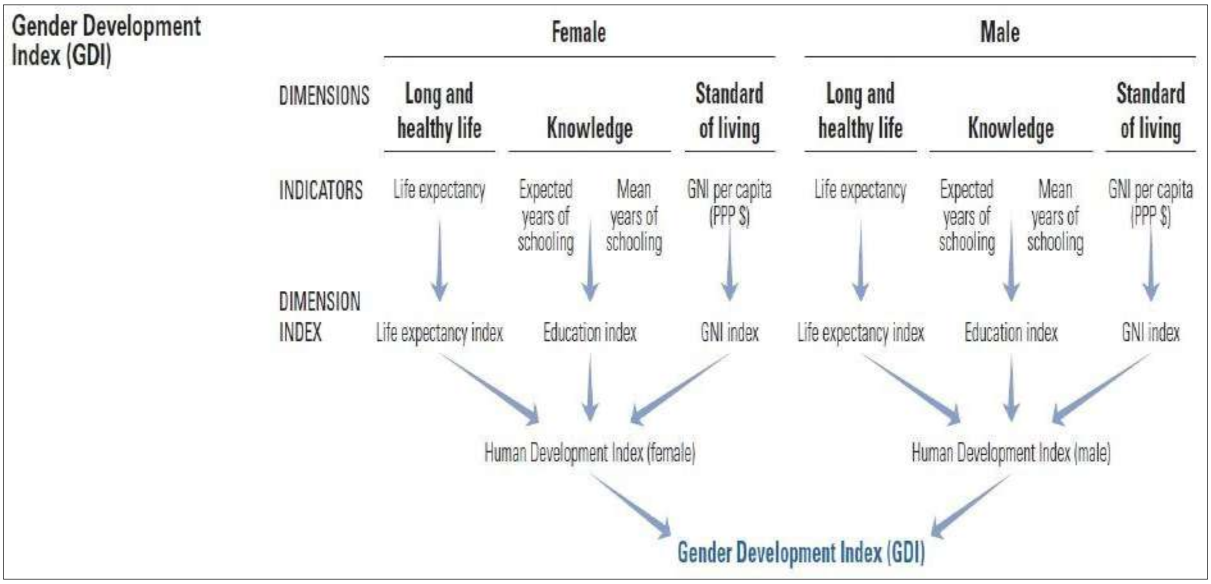
STEP 2: Individual Indices are computed first on the basis of a given formula. HDI is a simple average of these three indices and is derived by dividing the sum of these three indices by 3.

STEP 3: With normalization of the values of the variables that make up the HDI, its value ranges from 0 to 1. The HDI value for a country or a region shows the distance that it has to travel to reach the maximum possible value of 1 and also allows inter-country comparisons.



MAP 4.1: HUMAN DEVELOPMENT STATUS ACROSS THE WORLD

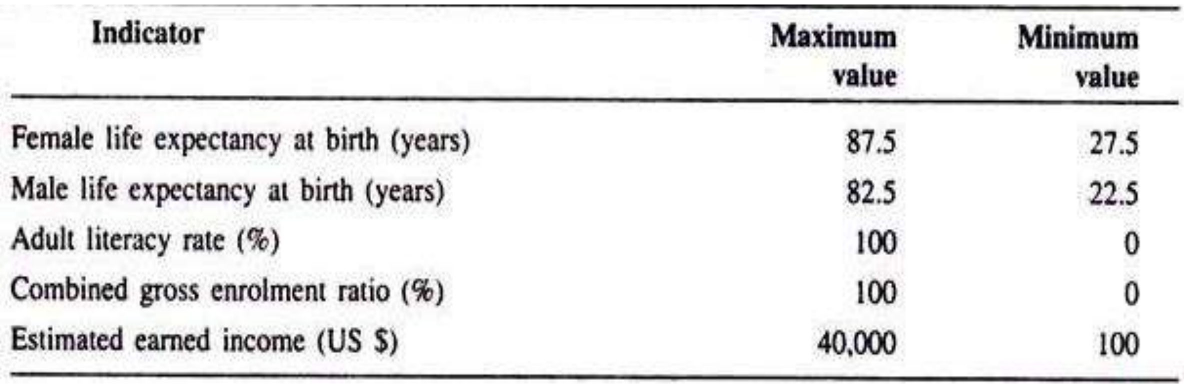
The Gender development index (GDI) measures gender gaps in human development achievements by accounting for disparities between women and men in three basic dimensions of human development—health, knowledge and living standards using the same component indicators as in the HDI. The GDI is the ratio of the HDIs calculated separately for females and males using the same methodology as in the HDI. It is a direct measure of gender gap showing the female HDI as a percentage of the male HDI. The GDI shows how much women are lagging behind their male counterparts and how much women need to catch up within each dimension of human development. It is useful for understanding the real gender gap in human development achievements and is informative to design policy tools to close the gap.



PROCEDURE:

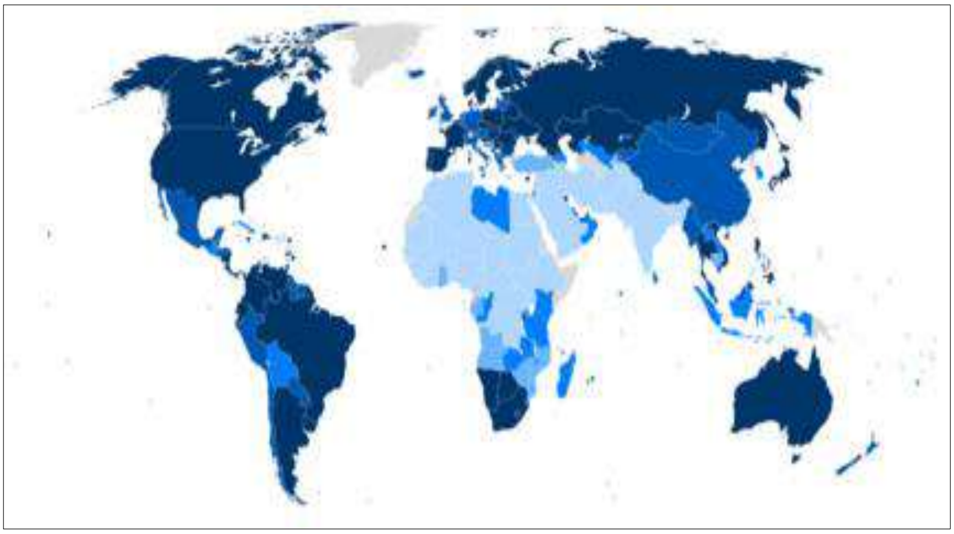
STEP 1: To calculate it, the HDI is first calculated separately for females and for males. The same goalposts as in the HDI are used for transforming the indicators into a scale lying between zero and one. The only exception is life expectancy at birth where the goalposts are adjusted, to reflect the empirical finding that on average, women have a biological advantage over men, and live about 5 years longer.

TABLE 4.1 GDI indicators and its goalpost



Indicator	Maximum value	Minimum value
Female life expectancy at birth (years)	87.5	27.5
Male life expectancy at birth (years)	82.5	22.5
Adult literacy rate (%)	100	0
Combined gross enrolment ratio (%)	100	0
Estimated earned income (US $)	40,000	100

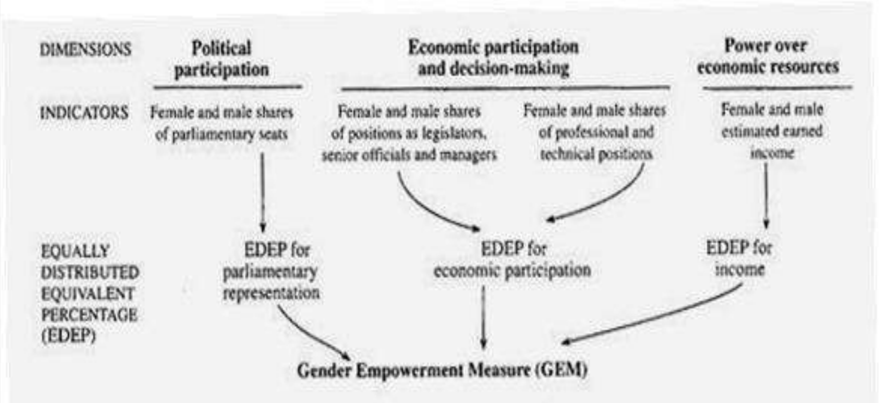
STEP 2: Ratio between female and male HDI will be calculated.



MAP 4.2: WORLD MAP SHOWING COUNTRIES IN GROUP 1 TO 5 OF THE GENDER DEVELOPMENT INDEX (based on 2018 data, published in 2019). Countries in Group 1 are closest to gender parity, while those in Group 5 are furthest (i.e. have the greatest gender disparity).

▮ Group 1 ▮ Group 2 ▮ Group 3	▮ Group 4 ▯ Group 5 ▯ Data unavailable

GENDER EMPOWERMENT MEASURE is a composite index measuring gender inequality in three basic dimensions of empowerment— economic participation and decision-making, political participation, and decision-making, and power over economic resources.



PROCEDURE: Calculating the GEM involves several steps.

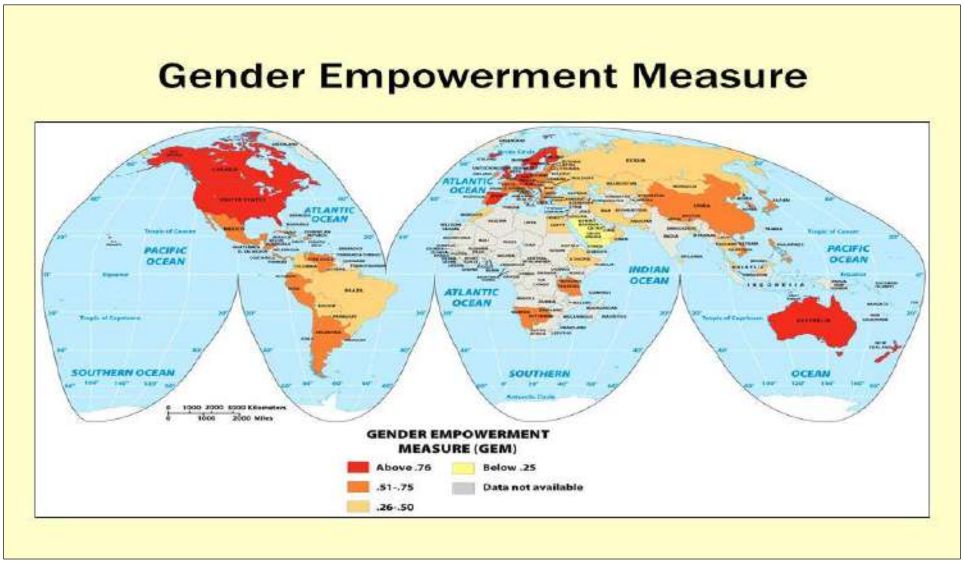
STEP 1: percentages for females and males are calculated in each of three areas.

- The first area is the relative number of parliamentary seats held.
- The second area is measured by two sub-components:
    - a) legislators, senior officials, and managers, and
    - b) Professional and technical positions.
- The third area is measured by the estimated earned income (at purchasing power parity US$).

STEP 2: for each area, the pair of gender percentages are combined into an Equally Distributed Equivalent Percentage (EDEP) that rewards gender equality and penalizes inequality. It is calculated as the harmonic mean of the two components.

The EDEP for economic participation is the unweighted average of the EDEP for each of its sub-components. The EDEP for income is computed from gender sub-values that are indexed to a scale from 100 to 40,000 (PPP US$).

STEP 3: the GEM is the unweighted average of the three Equally Distributed Equivalent Percentages.



MAP 4.3: MAPPING OF GEM

5. ESTIMATION OF HUMAN POVERTY INDEX – (HPI-I AND II) FOR DEVELOPED AND DEVELOPING COUNTRIES

The Human Poverty Index (HPI) is an indication of the standard of living in a country, developed by the United Nations (UN) to complement the Human Development Index (HDI) and was first reported as part of the Human Development Report 2007. It was considered to better reflect the extent of deprivation in developing countries compared to the HDI. In 2010, it was supplanted by the UN's Multidimensional Poverty Index.

The HPI concentrates on the deprivation in the three essential elements of human life already reflected in the HDI: longevity, knowledge and a decent standard of living. The HPI is derived separately for developing countries (HPI-1) and a group of select high-income OECD countries (HPI-2) to better reflect socio-economic differences and also the widely different measures of deprivation in the two groups.

For developing countries (HPI-1)

The Human Development Reports website summarizes this as "A composite index measuring deprivations in the three basic dimensions captured in the human development index—a long and healthy life, knowledge and a decent standard of living."

PROCEDURE:

STEP 1: Firstly, the percentages of three dimensions namely longevity failures, failure in knowledge, failure in decent standard of living are obtained.

STEP 2: HPI-1 is then calculated by taking symmetric average of order 3 of these three dimensions.

The formula for calculating it is:

- $\text{HPI-1} = 1/3\{ (P_1^{\alpha}) + (P_2^{\alpha}) + (P_3^{\alpha})\}^{1/3}$

$P_{1=}$ probability at birth of not surviving to age 40

$P_{2=}$ adult illiteracy

$P_{3=}$ unweighted average of population not using an improved water source and children underweight for age.

$\alpha = 3$

For selected high-income OECD countries (HPI-2)

The Human Development Reports website summarizes this as "A composite index measuring deprivations in the four basic dimensions captured in the human development index—a long and healthy life, knowledge and a decent standard of living—and also capturing social exclusion."

PROCEDURE:

Step 1: Firstly, the percentage from four dimensions namely longevity, knowledge, living standard, employment is obtained.

Step 2: HPI-II is then calculated by taking symmetric average of order 3 of these four dimensions.

The formula for calculating it is:

$$\text{HPI-2} = 1/4\ \{(P_1^{\alpha}) + (P_2) + (P_3) + (P_4)\}^{1/\alpha}$$

P_1 = Probability at birth of not surviving to age 60 (times 100)
P_2 = Adults lacking functional literacy skills
P_3 = Population below income poverty line (50% of median adjusted household disposable income)
P_4 = Rate of long-term unemployment (lasting 12 months or more)
$\alpha = 3$