ignou
THE PEOPLE'S
UNIVERSITY

Indira Gandhi National Open University
School of Interdisciplinary and
Trans-disciplinary Studies

MEVL-011
Environmental Science Lab Course – 1

PRACTICAL LAB MANUAL

Lab Course 1

M.SC. ENVIRONMENTAL SCIENCE PROGRAMME

PROGRAMME DESIGN COMMITTEE

Dr. Himanshu Pathak, Director, ICAR-National Rice Research Institute Cuttack, Odisha
Prof. P.A. Azeez, Director, SACON, Coimbatore
Prof I.S. Thakur, School of Environmental Sciences, JNU, New Delhi
Prof Uma Melkania, Dean, College of Basic Sciences and Humanities, GBPUAT, Pantnagar
Prof. Nidhi Rai, University College of Science, M.L. Sukhadia University, Udaipur
Prof. Jitendra Pandey, Centre of Advanced Study in Botany, BHU
Prof. R. Baskar, Department of Environmental Science & Engineering, Guru Jambheshwar University of Science & Technology, Hisar, Haryana
Prof. Jaswant Sokhi, SOS, IGNOU
Prof Neera Kapoor, SOS, IGNOU
Prof. P.K. Biswas, STRIDE, IGNOU
Prof. S.K.Yadav, SOA, IGNOU
Prof. Nandini Sinha Kapoor, SOITS, IGNOU
Prof. Shachi Shah, Director, SOITS, IGNOU
Prof. B. Rupini, SOITS, IGNOU
Dr. Surendra Singh Suthar, School of Environment & Natural Resources, Doon University, Dehradun
Dr. Vijay Kumar Baraik, SOS, IGNOU
Dr. Tanushree Bhattacharya, Department of Civil and Environmental Engineering, Birla Institute of Technology, Mesra, Ranchi
Dr. Pulak Das, School of Human Ecology, Ambedkar University, Delhi
Dr. Shubhangi Vaidya, SOITS, IGNOU
Dr. Sadananda Sahoo, SOITS, IGNOU
Dr. Sushmitha Baskar, SOITS, IGNOU
Dr. V. Venkat Ramanan, SOITS, IGNOU
Dr. Deeksha Dave, SOITS, IGNOU
Dr. Y.S.C. Khuman, SOITS, IGNOU

PROGRAMME COORDINATORS

Prof. Shachi Shah, SOITS, IGNOU
Dr. V. Venkat Ramanan, SOITS, IGNOU
Dr. Deeksha Dave, SOITS, IGNOU

Course Content Writer:
Dr. Girima Nagda (Assistant Professor
Deptt. of Zoology, M.L. Sukhadia University

Course Coordinator : Dr. Deeksha Dave, School of Interdisciplinary and Transdisciplinary Studies, Indira Gandhi National Open University, New Delhi

Course Content Editor : Prof. S. S. Katewa, Retd. Professor, Department of Botany, M. L. Sukhadia University, Udaipur.

Language and Format Editor : Dr. Deeksha Dave, School of Interdisciplinary and Transdisciplinary Studies, Indira Gandhi National Open University, New Delhi

PRODUCTION TEAM

Mr. Kulwant Singh
Assistant Registrar
MPDD, IGNOU, New Delhi

September, 2021

ISBN:

Printed and published on behalf of the Indira Gandhi National Open University, New Delhi by the Registrar, MPDD, IGNOU, New Delhi.

Laser Typeset by Tessa Media & Computers, C-206, Shaheen Bagh, Jamia Nagar, New Delhi-25

Printed at: Gita Offset Printers Pvt. Ltd., C-90, Okhla Ind. Area, Phase-I, New Delhi-20

Welcome to the first Semester laboratory course in Environmental Science. This manual gives the procedural details of various experiments you are required to perform in the course of this lab work. Each experiment contains Introduction, Objectives, Principles and Methodology.

INTRODUCTION

Environmental science is a dynamic subject involving both the living (biotic) and non-living (abiotic) components of the environment. It thus, demands thorough practical knowledge along with theoretical knowledge. Practical exercises give a deeper understanding and hand on experience of the theoretical concepts. Field studies are also an integral part of the practical exercises helping in experiential learning of the conceptual fundamentals.

This practical manual incorporates both field and laboratory exercises. It has a total of 20 exercises which will help in exploring various dimensions of environment by hands-on- experience and application-based approach. This manual will help to carry out these exercises in a systematic manner by explaining the concept, principle and the methodology.

These exercises include the following:

I. Exercises based on habitat and biodiversity indices

II. Exercises on abiotic and biotic components and productivity

III. Exercises on weather and climate analysis

IV. Exercises based on rocks and soil analysis

V. Exercises based on different statistical analysis

I EXERCISES BASED ON HABITAT AND BIODIVERSITY INDICES

EXPERIMENT 1

DETERMINATION OF MINIMUM SIZE OF THE QUADRAT BY 'SPECIES-AREA-CURVE' METHOD.

A quadrat is a tool used to record the abundance density frequency and coverage of a particular species in a study area. Quadrat method is one of the best ways for species analysis of a habitat. Quadrat is an area of definite size and is a basic sampling unit, used to sample any vegetation or habitat like grassland, etc. Quadrats are often square, circular or rectangular areas, of appropriate sizes that are placed at random in the study area. Presence or absence of species, numbers of organisms, or the percentage cover of each species is generally calculated within the quadrat. Quadrats are used to sample plants and may be used to sample some slow moving animals. The size of the quadrat is very important as too small or too large quadrat may not be representative of the community. The minimum size of quadrat for any particular area is that size in which maximum diversity of species can be recorded. It is different for different communities; areas etc.

The minimum size of quadrat suitable for a particular community can be determined by species area curve method. This method was at first designed by Braun-Blanquet in 1932.

A species-area curve is the relationship between the area of different sizes of a habitat and the number of species found within that area. The relative numbers follow systematic mathematical relationships. Larger areas tend to contain larger numbers of species and vice versa. Thus, the effect of the size of the area on the number of species found within a habitat or community led to the concept of minimal area i.e., "the smallest area which can contain an adequate representation of different species." An adequate representation will not only involve all the species which occur in that community but also the characteristic combination of species must occur on the area to be considered a minimal area. This "characteristic combination of species" involves:

1. The characteristic coverage of the "dominant species"
2. The characteristic homogeneity of structure as shown by the "constant species,‘‘ described in terms of presence, constance, and/or frequence; or
3. The presence of "characteristic species,'' i.e. those of high fidelity.

Thus, it is apparent, that the minimal area will vary greatly for different communities and it is equally obvious that this minimal area, which is said to be one of the characteristics of an association, can be determined only by empirical methods.

The species-area curve was quickly recognized as an important tool in community description and was used as a guide in the determination of minimal area of a community. There are many different ways in which such curves are constructed and they can be used for the determination of :

1. Minimal area of a community.
2. Minimum quadrat area in the single-plot or multiple-plot method, i.e. to determine the least size of quadrat

3. Least number of quadrats, of minimal size, which will give an adequate sample of a community to be used in obtaining either constancy or frequency data.

The shape of the species-area curve has been used to indicate the minimal area in the above cases. The point on the curve at which the curve flattens strongly and tends to become asymptote with the x axis (on which area is plotted) is taken to indicate the minimal area. It is shown that the shape of the species-area curve depends on the ratio between the y and x axes which is used in plotting the data.

1.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain the concept of minimal area in an area/community
- Explain and describe the concept of species area curve
- Know the importance of quadrat in various ecological analysis
- Know about appropriate size of the quadrat by using species area curve method
- Know how to use quadrat to record the abundance, density, frequency and coverage of a particular species in a study area

1.2 PRINCIPLE

Quadrat method is based on principle that as the size of quadrat gradually increases, there is increase in the number of the species in a quadrat to a certain point from where there is no further increase in the number of new or additional species.

The species-area curve is constructed by plotting the number of species found in a habitat on the y-axis and the area of the habitat on the x-axis. The area of habitat is independent variable plotted on x-axis and the occurrence of number of species in different areas is the dependent variable plotted on Y-axis. In this manner, when several areas of various sizes have been examined, it is found that the species-area points define a characteristic curve. This curve rises rapidly from the intersection of the y and x axes but sooner or later breaks its rate of rise and tends ultimately to become asymptote with the x-axis. The minimal area is taken to be that area at which the species-area curve becomes nearly a straight line and nearly horizontal.

The minimum quadrat size can be determined when the curve takes a horizontal shape indicating that the new species number does not increase. The point where the curve flattens is joined with the X-axis is regarded as the minimum area or minimum size of the quadrat. This method is very convenient for different types analysis like abundance or density of a particular species, presence or absence of species, numbers of organisms, or the percentage cover of each species etc.

1.3 REQUIREMENTS

Nails

Thread or string

Measuring tape or Measuring Scale

Graph paper

Hammer

Pencil

Note book

1.4 PROCEDURE

1. Select a suitable field rich in vegetation.
2. With the help of measuring tape, prepare a L-shaped structure of 100 × 100 sq. cm or 1 × 1 sq. metre size in the given area by using 3 nails and tie them with a thread/string.
3. Measure 10 cm on one side of the arm of L and the same on the other side of L and prepare 10 × 10 sq. cm area using another set of nails and string. Note the number of species in this area of 10 × 10 sq. cm.
4. Increase this area to 20 × 20 sq. cm and note the additional species growing in this area.
5. Repeat the same procedure for 30 × 30 sq. cm, 40 × 40 sq. cm and so on as shown in the figure 1 till there is no further increase in the total number of species with the increasing size of the quadrat. It is not necessary to cover 100 × 100 sq. cm area is the minimum size may less than this or more than this.

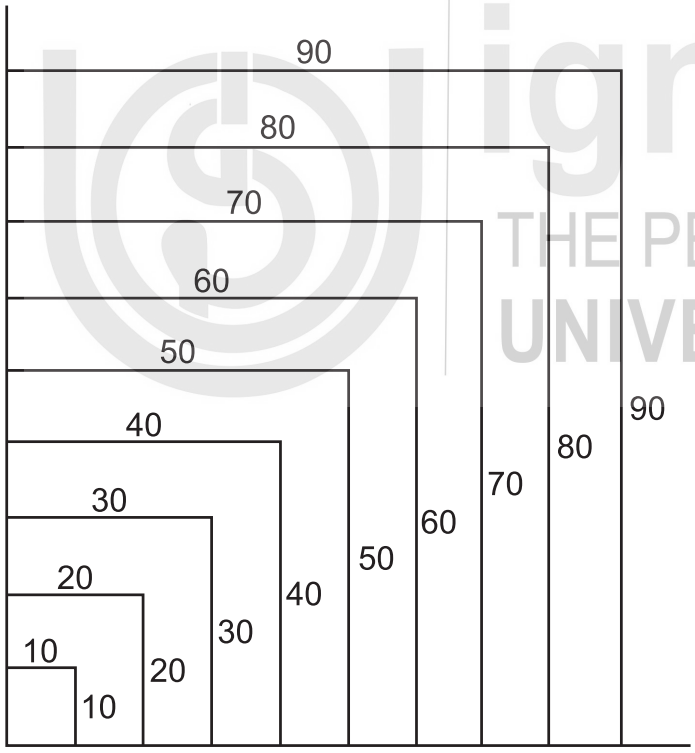


Fig. 1:Procedure for determining the minimum size of quadrat

6. Record all the readings as per the table given in observation table.
7. Plot a graph between areas/size of the quadrats on X- axis and the number of species found on Y-axis.
8. Draw a free hand curve and mark the point where the curve flattens as shown in the fig. 2. This is the point where the curve takes a horizontal shape indicating that the species number does not increase.
9. Join this point where the curve flattens with the X-axis and mark the area on x axis as shown in the fig. 2.

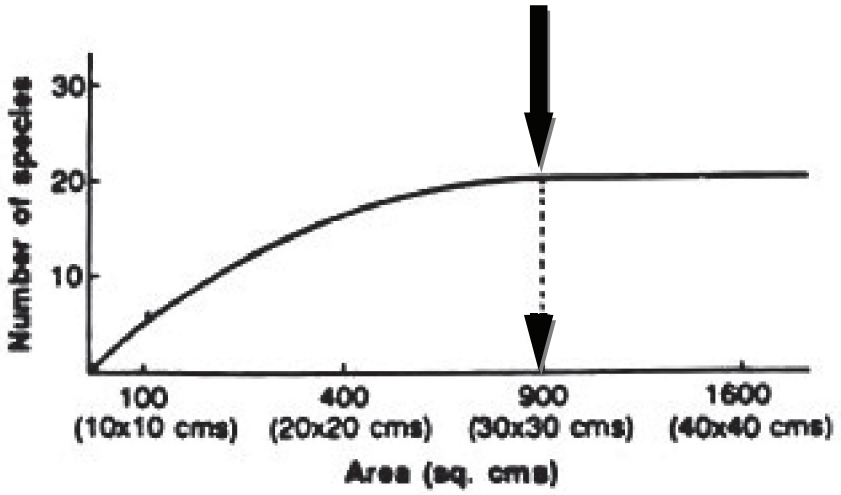


Fig. 2: Species area curve to determine the minimum size of the quadrat. Black Arrow indicates the point where the curve flattens and line arrow is the corresponding point on x axis regarded as the minimum size of quadrat.

1.5 OBSERVATIONS AND CALCULATIONS

Observation Table:

S. No.	Size (Sq. cm) of Quadrat	Total number of species
1	10 × 10	
2	20 × 20	
3	30 × 30	
4	40 × 40	
5	50 × 50	
6	60 × 60	
7	70 × 70	
8	80 × 80	
9	90 × 90	
10	100 × 100	

To find out the minimum size of quadrat corresponding to the occurrence of number of species, plot a graph between areas/size of the quadrats on X- axis and the number of species found on Y-axis. Draw a free hand curve and mark the point where the curve flattens and join this point with the X-axis and mark the area on x axis as shown in the fig. 2.

1.6 RESULT

From the species area curve, a maximum of …. species were found in the areas of …… …… ……. cm^2.

Thus, the minimum size of the quadrat in the present study area is …… cm^2. The smaller quadrat than …… cm2 could miss at least a species present in the study area.

1.7 PRECAUTIONS

1. Accurate size of quadrat areas need to be drawn carefully.

2. Be careful in counting the number of different species.
3. Try to make the quadrats of appropriate sizes with full accuracy
4. Plot the details on the graph accurately.
5. Record all observations carefully.
6. Area demarcated by 'L' shaped structure should not be disturbed.
7. Inadequate sampling will result in either over or under estimation.

EXPERIMENT 2

DETERMINATION OF FREQUENCY OF SPECIES BY LINE TRANSECT METHOD AND POINT FRAME METHOD

A community is a group of interdependent organisms inhabiting the same region and interacting with each other. In the community, the individuals of all the species are not evenly distributed. Individuals of some species are widely spaced while those of some other species are found in clumps or mats. The distribution patterns of individuals of different species indicate their reproductive capacity as well as their adaptability to the environment.

Frequency refers to the degree of dispersion in terms of percentage occurrence. In order to study the frequency of species in an area, the study area is sampled by any sampling method at several places in desired pattern or at random and only the names, not the numbers, of individual species encountered sample are listed.

Two ways in which scientists record data regarding communities in an ecosystem is to sample an area using the techniques called as transect and point method.

Transect method:

A **transect** is a path along which one counts and records occurrences of the species of study. A cross-section of an area used as a sample for recording, mapping or studying vegetation is called transect. It may be a strip, belt or a line across the area of study. The species occurring along these strips or lines are recorded. Because transect is continuous through the study area, it can be applied in studying the gradual and continuous changes in the vegetation along the line or strip with the change in environment. On the sloppy area, the transect is laid between two points at different altitudes. **The transects are of two types:**

(i) Belt transect (ii) Line transect.

In belt transect method the total area of the site to be studied is divided into a series of belts of predetermined width and length and the belts are divided into equal sized segments. Each segment within a belt is a part and the belt as a whole is one sampling unit.

In line transect sampling, the observer moves along a line through a study area, looking to the left and right for the animal or plant of interest. Line transects are walked, flown, or otherwise traversed, and the perpendicular distances to all detected items of interest are recorded. When an individual of the species of interest is detected, it is recorded, usually together with its distance from the line, because it is assumed that individuals that are far from the line are harder to detect than those that are close. This is one of the specialized ways that ecologists can use to estimate the density or the total number of animals or plants in a study area when it is not possible to simply count all the individuals and the standard sampling methods. For example, if the study area is very large and the species of interest is rare, then a random sample of quadrats in the study area may contain no individuals. However, if a long line is traveled through the area, then some individuals might be detected.

The size of items or other variables might influence the probability of detection, and such variables are sometimes included in the model that is used to correct for the items missed. The accurate estimation of the density or number of animals is always difficult using specialized methods like line transect sampling, and with all such methods, the final estimate obtained depends on the assumptions made. If these assumptions are not correct, then an estimate might be quite different from the true value.

Point Method:

In this method of sampling observations are taken on the point in the study area where a nail or set of nails touch the ground on grid lines or at random places.

Two common point methods of sampling are:

(i) Point centre method (ii) Point frame method.

Point centre or Quarter method:

In this method of sampling four measurements are taken at each observation point. The observation points can be mechanically placed along a straight line or they can be located at random. Quarter method was first described by Cotton and Curtis (1956). In this method an easy instrument is used which consists of a brass needle or a nail fitted with rubber cork and compass on the top.

Point frame method:

This method was introduced by Levy and Maiden (1933). It is done with the help of point frame. This consists of a scale like frame, supported by a pair of legs. The frame bears 10 equidistant holes having 60 cm long pointers or pins.

It is placed one after another at several observation points in the study area and the plant species that are hit by the pointed end of the Pointers or nails are recorded. Besides this, the number of times the species are hit and the total number of points taken are noted. From these values the quantitative structure of community is explained. This method is employed in the study of grassland and low herbaceous communities even on uneven ground.

2.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain about transect and point method of sampling
- Explain about line transect method
- Explain about point frame method
- Calculate frequency using line transect and point frame method

2.2 PRINCIPLE

Line Transect Method

In a line transect method a tape or rope marked off at 0.5 m intervals is laid along the area of ground to be sampled. The plant species that are touched or covered by the line are then recorded either all the way along or else at regular intervals. There may be many species which do not touch the line and are therefore not recorded and you may get results which may give a completely unrealistic sample of the community on which the line transect is made. Therefore, multiple line transects should be laid and data recorded. Line transect sampling is intended not only for the estimation of the abundance per unit area of rare, mobile, difficult-to-detect animals but also is of value for the study of rare, difficult-to-detect plants, intertidal organisms etc. The technique is related to variable circular plot sampling and is sometimes called distance sampling. A transect line can be made using a nylon rope marked and numbered at 0.5m, or 1m intervals, all the way along its length. This is laid across the area to be studied. The position of the transect line is very important and it depends on the direction of the environmental gradient

The usual assumptions made with line transect sampling are the following:

1. All objects on the transect line are detected.
2. Objects do not move in response to the observer before the detection is recorded.
3. Objects are only counted once.
4. Objects are recorded at the point of initial detection.
5. Distances are measured without errors.
6. Transect lines are randomly located in the study area.

Point Frame Method

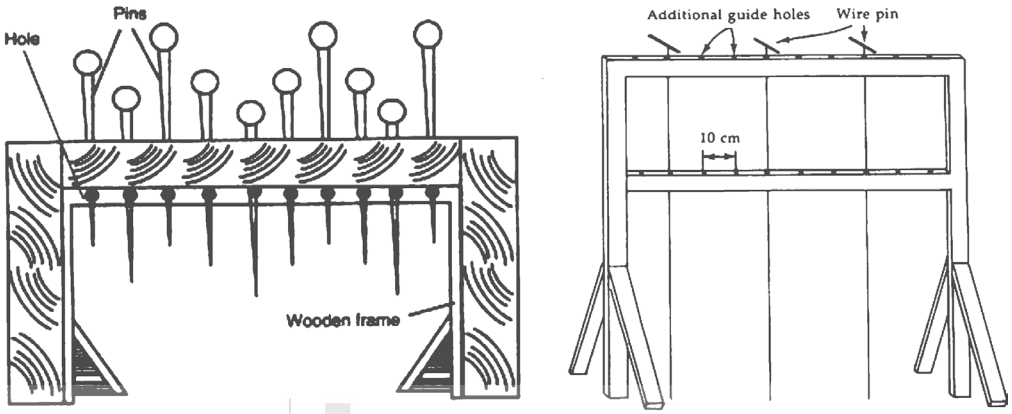


Figure. 2.1: Different types of Point Frame Apparatus

The point frame method was first suggested as an instrument to measure cover by Levy and Madden in the early 1930's. A point frame apparatus consists of a standing frame that holds a set of vertically aligned pins that are lowered as sampling points to record hits (Figure 2.1). The optimum number and arrangement of points within the frame depends on vegetation spatial patterns, distance between plants, and size of individual plants. A common configuration consists of 10 pins each 5 cm apart. Actual dimensions of the point frame should be selected so that the same plant is not hit by all pins.

Each point frame is usually considered the sample unit, so commonly cover data can be assessed in 10% intervals. Data from several frames are required for statistical analysis of cover data to compare differences between years or among sites. According to the objectives of the study, either ground cover, basal cover, canopy cover, or leaf area index can be determined by this method. The point frame provides reasonably accurate cover data, as long as enough points are observed. It is a much slower technique than sampling using the step point method, but eliminates much of the bias arising from subjective pacing. The point frame is best suited for grasslands and other low-growing vegetation. The point frame becomes impractical in taller shrublands because of difficulties in placing the point frame above tall plants. It is also best suited to vegetation with dense cover, where there is less likelihood that all points within the frame will record bare ground.

The frame is set up over the vegetation and the needles are lowered down through the plant canopy. Every time the point of a needle touches a plant, a “hit” is recorded with the species name. The needle can touch several plants before it eventually touches the ground surface. This is the only point sampling method that can give an accurate estimate of absolute cover of each species in multi-stratose vegetation, and hence an estimate of total leaf area for each species. All other methods give relative percentage cover.

2.3 REQUIREMENTS

- Point frame apparatus
- Line transect
- Graph Sheet
- String
- Notebook
- Pencil

2.4 PROCEDURE

Line Transect Method

Line transect is long string (calibrated) put across the vegetation and the plants touching the line are recorded.

Take a measuring take or a string marked at fixed intervals spread itacross the selected area.

Record the presence or absence of the species at marked intervals. Lay out many such transects in the study site.

1. A metric steel tape or steel chain is stretched across the study area.
2. The line is considered to be a one centimeter wide belt extending along one side of the tape or chain.
3. The nail is the zero meter mark of the line transect. Outside, the nail is pushed into the ground.
4. Unroll the string and place on the ground. The handle end is the 5-meter mark.
5. Go to the zero meter mark on the line. Standing on the line, stretch your arms out to both sides. All species found within arm's length on either side of the line are included in the survey population from the zero meter mark to the 1 meter mark.
6. Make a map of a community
7. Move along the lines and record plant species and the distance they cover along the line transect.
8. All items along the line transect should be identified, counted and then mapped.

Point Frame Method

1. Place the point frame one after another at several observation points in the study area.
2. Note and record the plant species that are hit by the pointed end of the Pointers or nails.
3. Also note the number of times the species are hit and the total number of points taken are noted.

2.5 OBSERVATION AND CALCULATIONS

Observation Table

S. No.	Name of Species	No. of sample plots (line or point)										No. of plots in which species occurs (X)	% frequency = (X/10)× 100
		1	2	3	4	5	6	7	8	9	10		
1	Species 1												
2	Species 2												
3	Species 3												
4	Species 4												
5	Species 5												

In point frame the frequency is calculated by the following formula:

Frequency of a species = Total no. of hits the species secured x 100 / Total hits made

2.6 RESULTS

The frequency of the 5 species was found to be as given:

S. No.	Species	Frequency by line transect method	Frequency by point frame method
1	Species 1		
2	Species 2		
3	Species 3		
4	Species 4		
5	Species 5		

2.7 PRECAUTIONS

1. The most important precaution to keep in mind is conservation of the environment.
2. During collection, damage to the habitat should be avoided because it causes adverse effect on organisms found there.
3. The centerline of the transect line must be straight and well marked.
4. Care must be taken that all species on the centerline are seen with certainty.

Belt Transect : Here instead of a string (line) a strip of some width (usually one meter) is several seqments and veqetation is studied in these seqments.

Method: Place belt transect across the study area. Record presence or absence of the species in alternate seqments. Take many such transects in different directions in the field.

EXPERIMENT 3

DETERMINATION OF RELATIVE FREQUENCY, DENSITY AND ABUNDANCE OF DIFFERENT SPECIES PRESENT IN THE COMMUNITY AND CALCULATION OF IVI

Communities are composed of the species occupying a site. Identification of patterns in community structure has been a major goal of ecological research. Community structure is the ecologist's term for indicating what organisms are present in a given environment, in what numbers, and how they relate to each other. The mix of species, including their number and relative abundance, defines the biological structure of a community. Community structure study is made by studying species richness, frequency, density, abundance and basal cover of species. The simplest measure of community structure is a count of the number of species occurring within the community, referred to as species richness. Frequency is the important parameter of community structure, which reflects the spread, distribution or dispersion of a species in a given area, and given in percent. For example, if a species is distributed uniformly in an area, there is greater probability of its occurrence in all quadrats and it would have maximum frequency. In another case, a species may be clustered or present only in a part of the area. In this case, it will occur only in few quadrats and hence it would have lesser frequency. Density is defined as the number of individuals of a particular species per unit area. Abundance is also calculated like density but in this case, only those quadrats are considered for calculation where a species actually occurs.

Abundance and Density, both terms refers to the number of species in a community. **Abundance** of any individual species is expressed as a percentage of the total number of species present in community and therefore it is a relative measure. In sampling the abundance of species the individuals of species are counted instead of just noting their presence or absence as was done while studying the frequency of a species.

Taken together abundance and frequency are of great importance in determining the community structure.

Dominance is measure of the size, bulk, or weight of the vegetation. Three characteristics of the vegetation are commonly evaluated as a measure of dominance: weight, basal cover, or canopy (crown) cover of area. Weight measurements are often difficult and time consuming to obtain and the latter two measures are more often evaluated.

But these data do not provide an overall picture of importance of a species, e.g., frequency gives us an idea about dispersion of a species in the area but does not give any idea about its number or the area covered. Density gives the numerical strength and nothing about the spread or cover. The Importance Value Index (IVI) shows the complete or overall picture of ecological importance of the species in a community. IVI is statistical measure, which gives an overall picture of the importance of the species in the community. It considers the relative values of density, frequency and basal area of every species in a given area. It thus incorporates three important parameters, which are measures of diversity and productivity of every species.

3.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Define community structure

- Know and calculate frequency, dominance, abundance and density
- Know and calculate relative frequency, relative abundance and relative density
- Know and calculate IVI

3.2 PRINCIPLE

Frequency: Frequency is the number of sampling units or quadrats in which a given species occurs.

Percentage frequency (%F) can be estimated by the following formula:

$$\%\ \text{frequency (F)} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

Relative frequency (RF) of a species is calculated by the following formula:

$$\mathbf{RF} = \frac{\textbf{Number of quadrats in which a species occurs}}{\textbf{Number of quadrats in which all the species occurs}} \times \mathbf{100}$$

Thus, if a species occurs in 5 out of total 10 quadrants studied, its frequency would be 50%. If a species occurs in all the quadrats studied, its frequency would be 100%. Frequency is a very important quantitative parameter. Raunkiaer (1934) made an elaborative study on the frequency of species in about 8000 quadrats and based on his data, he divided species into 5 classes viz. A, B, C, D, E. The distribution of frequency in 5 classes is given here under in Table 3.1

Raunkiaer's Frequency Class	Frequency Range
A	1-20%
B	21-40%
C	41-60%
D	61-80%
E	81-100%

Table 3.1: Raunkiaer's Frequency class distribution

Density: Density may be defined as the number of species per specified collection area. **Density is the number of individuals per unit area and can be calculated by the following formula:**

The density value, thus obtained for each species is expressed as individuals per unit area.

The relative density is the study of numerical strength of a species in relation to

$$\text{Density (D)} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}$$

The relative density is the study of the numerical strength of a spaces in relation to total number of individuals of all species and calculated as:

Relative density (RD) of a species is calculated by the following formula:

$$\text{RD} = \frac{\text{Total number of individuals of a particular species in all quadrats}}{\text{Total number of individuals of all the species in all quadrats}} \times 100$$

Abundance: Abundance is described as the number of individuals per quadrat of occurrence.

Abundance for each species can be calculated by the following formula:

$$\text{Abundance (A)} = \frac{\text{Total number of individuals}}{\text{Number of quadrats of occurrence}}$$

For example, if a species has occurred in only 3 quadrats out of total 5 studied, then the total number of individuals of the species is divided by 3 (instead of 5, as in case of density).

Abundance does not give a total picture of the numerical strength of a species in an area because only the quadrats of occurrence are taken into consideration and not all the quadrats studied. Abundance is also presented on the basis of unit area, i.e. 1m2, especially in smaller areas or grasslands. However, it is not much used as compared to density in ecological studies. It can also be multiplied by 100 to get percent abundance.

Dominance: Dominance is measure of the size, bulk, or weight of the vegetation. Three characteristics of the vegetation are commonly evaluated as a measure of dominance: weight, basal cover, or canopy (crown) cover of area. Weight measurements are often difficult and time consuming to obtain and the latter two measures are more often evaluated.

Dominant species are those which are highly successful ecologically and determine (to a considerable extent) the condition under which the associated species must grow. It can be calculated as follows:

$$\textbf{Dominance} = \frac{\textbf{Total basal area or crown}}{\textbf{Total area sampled}}$$

Relative dominance is the relative proportion of different species in the community.

Relative dominance of a species is calculated by the following formula:

$$\textbf{Relative Dominance} = \frac{\textbf{Dominance of given species}}{\textbf{Total dominance of all species}} \times \textbf{100}$$

or

$$\text{Relative dominance} = \frac{\text{Total basal area of a particular Relative species in 5 quadrats}}{\text{Total basal area of all the species in 5 quadrats}} \times 100$$

Basal area of a plant species is calculated by the following formula:

Basal area of a species = πr^2

where π = 3.142, and r = radius of the stem

Importance Value Index: For finding IVI, the percentage values of relative frequency, relative density and relative dominance of a species are added together, and this value out of 300 is called Importance Value Index or IVI of a species.

Thus,

IVI = Relative density + Relative frequency + Relative dominance

The sum of the IVI of all the species in a community composed of several species should equal 300.

3.3 REQUIREMENTS

- Wooden quadrat of 1×1 metre,
- Pencil,
- Notebook.
- Metre scale,
- String

3.4 PROCEDURE

1. Lay a quadrat in the field or specific area to be studied.
2. Note carefully the plants occurring there.
3. Complete the Table 3.2 as per the species present in the limits of your quadrat.
4. Lay at random at least 5 quadrats in the same way and record your data in the form of table.
5. Calculate the frequency, density and abundance by the formula given.
6. Determine the relative frequency, relative density and relative dominance. Calculate the IVI

3.5 OBSERVATIONS AND CALCULATIONS

Observation Table

S. No.	Name of Species	No. of sample plots (line or point)					Total Individuals	No. of quadrats in which species occured	Frequency	% frequency	Abundance	Density
		1	2	3	4	5						
1	Species 1											
2	Species 2											
3	Species 3											
4	Species 4											
5	Species 5											

Calculations:

$$\textbf{Dominance} = \frac{\textbf{Total basal area or crown}}{\textbf{Total area sampled}}$$

$$\textbf{Relative Dominance} = \frac{\textbf{Dominance of given species}}{\textbf{Total dominance of all species}} \times \textbf{100}$$

Or

$$\text{Relative dominance} = \frac{\text{Total basal area of a particular Relative species in 5 quadrats}}{\text{Total basal area of all the species in 5 quadrats}} \times 100$$

Percentage frequency (%F) can be estimated by the following formula:

$$\%\ \text{frequency (F)} = \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats studied}} \times 100$$

Relative frequency (RF) of a species is calculated by the following formula:

$$\mathbf{RF} = \frac{\textbf{Number of quadrats in which a species occurs}}{\textbf{Number of quadrats in which all the species occurs}} \times \mathbf{100}$$

$$\text{Density (D)} = \frac{\text{Total number of individuals}}{\text{Total number of quadrats studied}}$$

Relative frequency (RF) can also be expressed as:

$$= \frac{\textbf{Number of occurrences of one species}}{\textbf{Number of occurrences of all species}} \times \mathbf{100}$$

Or

$$= \frac{\textbf{Frequency of the species}}{\textbf{Frequency of all the species}} \times \mathbf{100}$$

Relative density (RD) of a species is calculated by the following formula:

$$\text{RD} = \frac{\text{Total number of individuals of a particular species in all quadrats}}{\text{Total number of individuals of all the species in all quadrats}} \times 100$$

IVI = Relative density + Relative frequency + Relative dominance

3.6 RESULTS

- Report the % frequency, abundance, density, dominance and IVI for all the species studied.
- The most frequently occurring species was found to be _____
- The most dominating species was found to be _____
- The Highest IVI was found in _____

EXPERIMENT 4

DETERMINATION OF STANDING CROP AND BIOMASS IN TERRESTRIAL ECOSYSTEM.

Biomass is the weight or total quantity of living organisms of one animal or plant species (species biomass) or of all the species in a community (community biomass), commonly referred to a unit area or volume of habitat. Biomass is biological material derived from living organism. The biomass of a species is expressed in terms of fresh or dry weight.

The weight or quantity of organisms in an area at a given moment is the standing crop. Standing crop includes current year's production together with that produced in previous years. Standing crop at a site fluctuates within and among years, depending on seasonal conditions and utilization by grazing animals. This is abundance of organisms existing in the area at any one time. It may be expressed in terms of number of individuals, as biomass of organisms, as energy content or in some other suitable terms. Measurement of standing crop reveals the concentration of individuals in various populations of the ecosystem.

4.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Define Biomass
- Define Standing crop
- Calculate Standing crop and biomass

4.2 PRINCIPLE

Biomass is usually expressed as dry weight of all the living materials (plants as w ell as animals) in an area. Under biomass we include plants (their aboveground and underground parts) as well as animals. Fallen leaves and twigs of the plants are also taken in consideration at the time of studying biomass.

Standing crop is the mass of living material that each trophic level has at a particular time. The standing crop is measured as the mass of living organisms (biomass) or the number in a unit area. The biomass of a species is expressed in terms of fresh or dry weight. Measurement of biomass in terms of dry weight is more accurate.

Both are calculated using dry weight mechanism

4.3 REQUIREMENTS:

- Quadrat or (Nails, Metre scale, String)
- Plougher or a weeding instrument
- Digger
- Polythene bags,
- Oven
- Digital weighing balance

4.4 PROCEDURE

1. Take an appropriate size quadrat or make an area of say 50×50 cm2 in the grass field.
2. Weed out all the above-ground parts of the plants growing in that limit with the help of weeding instrument. Collect all of them in a polythene bag (A).
3. Collect the fallen leaves, litter and other parts of the plants in the second polythene bag (B).
4. Collect all the animals such as ants, larvae, earthworms, insects, etc., in the third polythene bag (C).
5. By digging the soil to about 20 to 25 cm., take out all the underground parts of the plants and collect them in a separate bag after washing (D).
6. In the same way lay some more quadrats in the area under study and collect all the materials in polythene bags.
7. Place the collected material of each bag individually on tissue paper or in a large beaker and keep them in the drying oven for seventy-two hours (3 days).
8. After the 3 day drying time, remove the samples from the drying oven and let them cool. When cool, weigh the sample.

4.5 OBSERVATIONS AND CALCULATIONS:

i. Area studied : 50×50 cm2

ii. Dry weight of aboveground parts (A) = _____ grams.

iii. Dry weight of fallen leaves litter etc. (B)= _____ grams.

iv. Dry weight of animals (C) = _____ grams.

v. Dry weight of underground parts (D) = _____ grams.

vi. Total dry weight = A +B+ C+ D grams.

vii. Biomass = Total dry weight/ Area studied _____ grams/ cm2

viii. Standing crop = A + C+ D grams.

4.6 RESULTS

The standing crop of the field was found to be _____ grams

The biomass of the field was found to _____grams/ cm^2

4.7 PRECAUTIONS

1. While removing complete plant be careful not to harm the existing fauna
2. Be careful while handling the oven

II EXERCISES ON ABIOTIC AND BIOTIC COMPONENTS AND PRODUCTIVITY

EXPERIMENT 5

STUDY OF THE ABIOTIC AND BIOTIC COMPONENTS OF AN AQUATIC ECOSYSTEM.

An Ecosystem is defined as an ecological unit consisting of the complex of living organisms, their physical environment, and all their interactions and interrelationships in a particular unit of space. Every ecosystem basically consists of two components: abiotic (non-living) and biotic (living)

The abiotic components consist of three sub components:

i. Climatic conditions and physical factors of the given region such as precipitation, temperature, light, moisture, soil etc.

ii. Inorganic substances such as carbon, water, phosphorus, sulphur, nitrogen, hydrogen etc. which are involved in cycling of nutrients in the ecosystem. The amount of these inorganic substances present at any given time in an ecosystem is called as the standing state or standing quality.

iii. Organic substances such as carbohydrates, proteins, lipids, humic substances etc. present either in the biomass or in the environment

In the trophic structure of any ecosystem the biotic components or the living organisms are distinguished on the basis of their nutritional relationships. They consist of two major sub-components:

i. Autotrophic component: They include the producers or autotrophs which produce their own food. They can either be photoautrophs or chemoautotrophs

ii. Heterotrophic component: They are the consumers and cannot produce their own food and consume the material built by producers. They are of two types:

- Macroconsumers: which include primary, secondary and tertiary consumers
- Microconsumers: also called as decomposers, saphrotrophs, reducers, osmotrophs and scavengers. They feed on dead organic matter.

Ecosystem can be natural or artificial. Natural ecosystem includes terrestrial ecosystem (forest, grassland, deserts etc.) and aquatic ecosystem (Fresh water or marine). Artificial ecosystems are man-made like croplands, dams, aquarium etc.

5.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Know about structure of ecosystem
- Know about the various abiotic and biotic components of an ecosystem
- Study and measure the abiotic components (pH, light intensity and temperature) of pond ecosystem
- Study the biotic components of pond ecosystem

5.2 PRINCIPLE

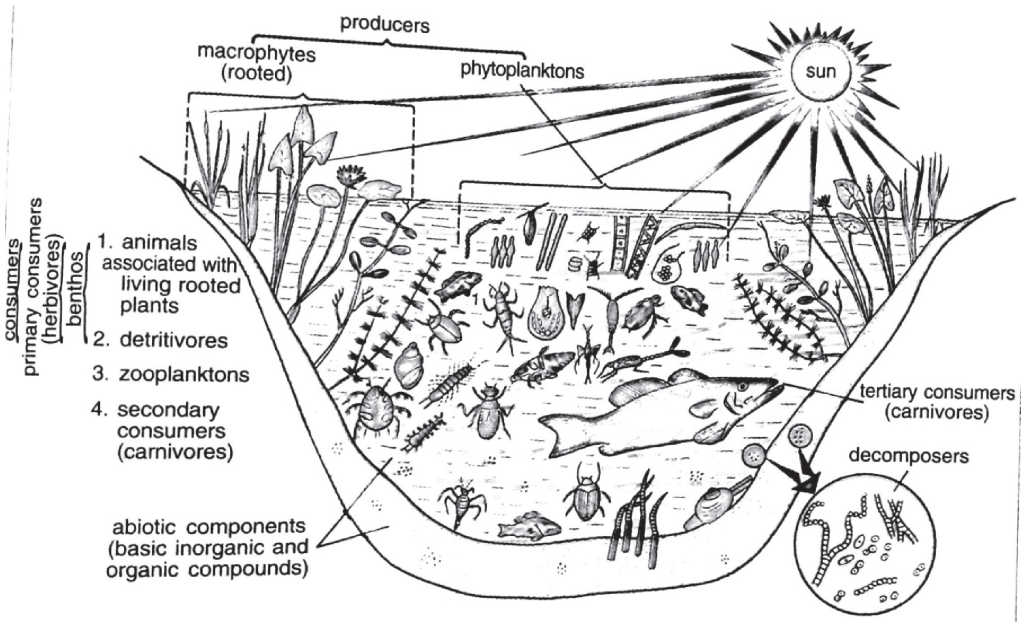


Figure 5.3: A pond ecosystem showing the abiotic and biotic components

A pond as a whole serve as a good example of an aquatic and freshwater ecosystem. In fact, it represents a self-sufficient and self-regulating system. It has following abiotic and biotic components

1. Abiotic Components

The chief non-living or abiotic substances are heat, light, pH value of water, and the basic inorganic and organic compounds, such as water itself, carbon dioxide gas, oxygen gas, calcium, nitrogen, phosphates, amino acids, humic acid, etc. Inorganic salts occur in the form of phosphates, nitrates and chlorides of sodium, potassium and calcium. Some proportion of nutrients exists in solution state but most of them are present as stored in particulate matter as well as in living organisms.

i. **pH:** pH is the measure of hydrogen ions, or acidity, in the water. Water has hydrogen ions and hydroxyl ions. When there are equal numbers of both, the water is neutral. As the hydrogen ions increase, the water becomes more acidic; as the hydroxyl ions increase, the water becomes more basic. pH is measured on a logarithmic scale of 0 – 14: 7 is neutral; below 7 is acidic; above 7 is basic. Most aquatic organisms have a narrow pH tolerance range of 6.5 – 8.5. Acidic waters can cause toxic heavy metals to be released into the water. Acid rain and mining operations can lower the pH of water bodies. pH of the water can be tested by pH meter, pH paper or B.D.H. Universal Indicator.

ii. **Light Intensity:** Light is a master variable in aquatic ecosystems. Light intensity and spectral distribution hold the key to understanding the dynamics and variability of physical, biological and chemical processes on all scales in aquatic ecosystems. It is a major driver of energy and material flow through aquatic ecosystems it can also be a limiting or co-limiting resource as well as a basis for competition. For example, light introduces heat in the upper water layer, drives primary production, and degrades substances. The quantity and spectral composition of underwater light is highly variable, nevertheless, a common set of physical and optical principles govern the light climate in

all environments such that general insights can be drawn from studies of both marine and freshwater systems. Light intensity available to the pond is measured with the help of 'photometer.' A 'photometer' consists of a photoelectric cell and a micro-ammeter. Photometer for pond is specially sealed in water-tight containers fitted with a glass window. Photoelectric cell is sensitive to light and generates current when light falls on it. Light intensity is proportional to the current generated in the photoelectric cell by the light falling on it. Readings can be noted in micro-ammeter. The light intensity is calculated by the following formula:

Light Intensity = r × 100 / a

where r = Reading of lux-meter or photometer

a = Reflected light from the cardboard.

iii. **Temperature:** Every organism has an optimal temperature range in which it thrives. An organism may be able to survive at warmer or cooler temperatures, but it will do so under stress, which requires more energy (and therefore food), and decreases its' ability to compete for other resources within the ecosystem. This is particularly important for ectothermic (cold-blooded) organisms, which are a majority of marine animals.

Temperature affects aquatic organisms in a variety of ways. The body temperature of most aquatic organisms is the same as the surrounding water and fluctuates with the water temperature. Most aquatic organisms are adapted to live in a narrow temperature range and they die when the temperature becomes too low or too high. Temperature affects their metabolism, reproduction and emergence. Temperature also affects the rate of photosynthesis of aquatic plants, the base of the aquatic food web. Pollutants can become more toxic at higher temperatures. The amount of dissolved oxygen becomes lower as the water becomes warmer. Temperature is measured in degrees Fahrenheit or Celsius (Centigrade). A change in temperature can also influence the pH of water. Temperature of water can be measured using a Thermistor. It is an instrument which gives correct reading of temperature in centigrade. It consists of a glass globule with thermocouple, electric cord and potentiometer with graduated scale. It contains a long cable. At the end of the cable is attached a thermocouple. A millimeter is present which is calibrated in C° and gives direct reading.

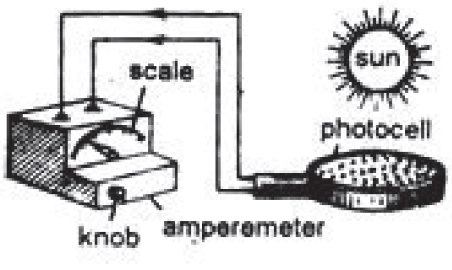


Figure 5.1: Photometer

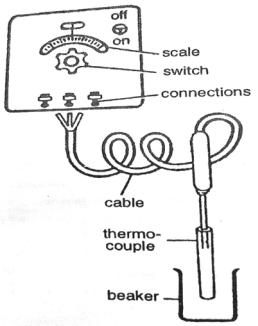


Figure: 5.2: Thermistor

2. Biotic Component

lt includes various organisms which are classified into the following types

a. **Producers:** These are photoautotrophic green plants and photosynthetic bacteria. The producers fix radiant energy of sun and with the help of minerals

derived from water and mud; they manufacture complex organic substances as carbohydrates, proteins and lipids. Producers of pond are of following types:

i. **Macrophytes:** These include mainly the rooted large-sized plants which comprise three types of hydrophytes: partly or completely submerged, floating and emergent aquatic plants. The common plants are species of *Nymphaea*, *Chara*, *Hydrilla*, *Vallisneria*, *Utricularia*, *Marsilea*, *Nelumbo*, etc. Besides these plants, some free floating forms also occur in the pond ecosystem, e.g., *Azolla*, *Salvinia*, *Wolffia*, *Eichhornia* etc.

ii. **Phytoplanktons:** These are microscopic (minute), floating or suspended lower plants (algae) that are distributed throughout the water, but mainly in the photic zone. Most of them are filamentous algae such as *Spirogyra*. *Ulothrix*, *Zygnema*, *Cladophora* and *Oedogonium*. There also occur some chlorococcales (e.g., *Chlorella*), *Closterium*, *Volvox*, *Diatoms*, *Anabaena*, *Oscillatoria*, *Chlamydomonas*, *Spriulina*, etc., and some flagellates.

b. **Macroconsumers:** They are phagotrophic heterotrophs which depend for their nutrition on the organic food manufactured by producers, the green plants. Macroconsumers are of following three types:

i. **Primary consumers (herbivores):** They feed directly on plants or their remains. These include fish, insects, mollusks, crustaceans, etc. and zooplanktons which feed chiefly on the phytoplanktons and are rotifers like *Brachionus*, protozans like *Euglena*, *Dileptus*, etc., and crustaceans such as *Cyclops*, *Stenocypris*, etc

ii. **Secondary consumers:** These carnivores feed on the herbivores and include chiefly insects, fish and amphibians (frog). Most insects like water beetles, nymps of dragon fly etc. which feed on zooplanktons or aquatic insects.

iii. Tertiary consumers: They are the large fishes

c. **Decomposers:** They are also called microconsumers, since they absorb only a fraction of the decomposed organic matter. They bring about the decomposition of dead organic matter of both producers (plants) as well as macroconsumers (animals) to simple forms. Decomposers help in returning of mineral elements again to the medium of the pond and in running biogeochemical cycles. Decomposers of pond ecosystem include chiefly bacteria, actinomycetes and fungi.

5.3 REQUIREMENTS

- Collection nets with different mesh sizes
- Metallic chains with hooks
- Specimen tubes
- Glass jars
- Hand lens
- Scissors
- Forceps
- Microscopes
- Stains

- pH universal indicator or pH paper or pH meter
- Thermistor and
- Sealed photometer in water tight containers with glass windows.

5.4 PROCEDURE

ABIOTIC COMPONENTS

1. Light intensity:

For determining light intensity, place the sealed photometer at different sites and depths in pond and note directly the reaching light intensity.

2. pH :

i. For determining pH of a pond water, collect water of pond from different places and depths.

ii. Keep these water samples in different wide mouthed glass stopper bottles.

iii. Mark these bottles according to the place of their collection.

iv. Take 5 ml of water of a bottle, add few drops of universal indicator.

v. Compare the colour developed with the colour chart pasted on the indicator bottle and find out approximate pH.

vi. Determine pH of all the bottles and make a chart showing place of collection and pH.

2. Temperature

i. Collect pond water in a beaker.

ii. Dip the glass globule in beaker holding with hands.

iii. Switch on potentiometer and note directly the temperature indicated by the needle.

iv. Note the temperature of the pond at different places and at different depths.

BIOTIC COMPONENTS

1. Plants and animals from pond could be collected by nets and placed in jars and polythene bags.
2. Pond water with vegetation could be collected in a glass trough also.
3. Metallic chains and hooks may be used to collect various plants.
4. Planktons (algae and protozoans) are collected by nylon nets.
5. Bring pond water sample to laboratory for further examination under microscope
6. Observe three biotic components of pond ecosystem namely producers, consumers and decomposers.

5.5 OBSERVATIONS AND CALCULATIONS

1. Calculate the light intensity by the following formula:

   Light Intensity = r × 100 / a (expressed in lux)

   where r = Reading of lux-meter or photometer

   a = Reflected light from the cardboard.

2. Note the pH
3. Note the temperature
4. Observe and note the following 3 types of biotic components:

i. Producers:

a. Submerged:

b. Free floating:

c. Rooted floating:

d. Amphibious:

e. Phytoplankton:

ii. Consumers:

a. Primary:

b. Secondary:

c. Tertiary:

iii. Decomposers:

5.6 RESULT

Report all the observations

5.7 PRECAUTIONS

Be careful near the pond and do not harm the plants and animals.

EXPERIMENT 6

ESTIMATION OF NET PRIMARY PRODUCTIVITY BY HARVEST METHOD IN GRASSLAND ECOSYSTEM.

The productivity of an ecosystem refers to the rate of production that is the amount of organic matter accumulated at any time. It is the rate at which energy is accumulated by green plant in unit time in the form of organic substance that can be used as food. In other words the rate of biomass production is called productivity.

Productivity in ecosystems is of two kinds, i.e., primary and secondary. Green plants fix solar energy and accumulate it in organic forms as chemical energy. As this is the first and basic form of energy storage, the rate at which the energy accumulates in the green plants or producers is known as primary productivity. Secondary productivity is the rate of energy storage at consumer's level.

Primary Productivity is the rate at which radiant energy is stored by photosynthetic activity of green plants and algae in the form of organic substance. It is called primary because it is the first and most basic form of energy stored in the ecosystem. Primary productivity is the productivity at the producer level. It can be termed as the amount of organic matter produced by the plants from solar energy in a given area during a given period of time. Primary productivity is of two types:

(i) Gross Primary Production (GPP): This refers to the total amount of organic matter produced. This can also be defined as total energy captured by the photosynthetic organism. This will depend on the photosynthetic capacity of the producer and environ¬mental factors.

The total photosynthesis that is all of the sun's energy that is assimilated is called gross primary production or GPP. It includes the organic matter used up in respiration during the measurement period. It is also called total assimilation. It is given as:

Gross primary production (GPP) =net primary production (NPP) + respiration (R)

(ii) Net Primary Production (NPP): It is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the measurement period. In other words, energy remaining after respiration and stored as organic matter during the period of measurement is known as net primary production. It is also called apparent photosynthesis. It is the net stored energy in the green plants. This is the net accumulation of biomass which serves as food for herbivores and decomposers. NPP is said to be a measure of amount of organic matter produced in a community in a given time available to the heterotrophs. Net production is the energy available to the heterotrophic components of the ecosystem. A portion of net primary production is used by plants for growth to build up components such as stem and leave and a portion stored for future growth and other functions. NPP results in the accumulation of plant biomass, which serves the food of herbivores and decomposers. It is given as:

Net primary production (GPP) = Gross primary production (GPP) - respiration (R)

Productivity in terrestrial ecosystem is influenced by numerous factors: carbon dioxide, light, temperature, moisture, nutrients, soil texture, biotic activities (i.e., grazing, above ground herbivores, below ground herbivores, predators and parasites and diseases of primary producers), anthropogenic factors etc. In aquatic systems, productivity is generally limited by light, which decreases with increasing water depth. In deep oceans nutrients often become limiting for

productivity. Nitrogen is most important nutrient limiting productivity in marine ecosystems. The most productive ecosystems are those with optimal levels of such factors, ultimately to maximize photosynthesis. These factors exert their influence simultaneously and interactively often doing so in a non equilibrium manner.

Productivity is usually measured as the rate at which energy or biomass is produced per unit area per unit time. This rate is expressed in as kilocalories per square meter per year (kcal/m^2/yr) or if it is measured as energy it is expressed as grams per square meter per year a measure of biomass or dry mass (g/m2/year). Various techniques used to estimate primary productivity are

- Harvest Method
- Light and Dark Bottle Method
- Radioactive Tracer Method
- Chlorophyll Concentration
- Carbon Dioxide Flux
- Oxygen Diurnal curve method
- Dimension Analysis

6.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain about productivity of an ecosystem
- Explain about net and gross primary productivity
- Know about different methods of estimating Net primary productivity
- Calculate Net Primary Productivity of a grassland ecosystem by harvest method

6.2 PRINCIPLE

Harvest method is widely used to estimate productivity in terrestrial ecosystem. It is the most common and at the same time oldest method of measuring primary production. It is most useful for estimating the production of cultivated land, range land and communities of annual plants where production starts from zero at seedling or planting time and becomes maximum at harvest, predation is very low thus, minimal use by consumers. Farmers use it to estimate yields from their crop fields. It is used to estimate primary production in eco systems where a steady-state condition is never reached and in which herbivores do not remove much material, as in terrestrial ecosystems, particularly cultivated crop fields. In this method, efforts are made to prevent insects and other herbivores from removing grains from the crop field. At the time of planting seeds in the field, the rate of production remains zero, while it reaches a maximum at harvest time. This method measures the net primary production in one growing season taking the difference in the weight of seeds sown and the final harvested products, such as grains, straw, stem and roots. It is very simple to measure net primary production. The ecologist can remove the roots, stems, straw and grains either from a grassland or a cultivated crop field, periodically or after the growing season, to estimate the net primary productivity. The materials removed by herbivores are not taken into account and neither the energy spent by plants for their maintenance nor the GPP is measured. This method is extremely convenient for measuring the NPP in grasslands and crop fields. Sample areas are harvested at intervals throughout

the growing season, and the material is dried to estimate dry weight or calorific value. The method may also be used for woodlands, although usually only one final felling and dry-weight estimation is feasible. In such situations it is generally more reliable and ecologically more desirable to use indirect, non-destructive estimates, e.g. by monitoring carbon dioxide profiles. The harvest method is usually used only for above-ground biomass and therefore neglects the large and important development of root biomass below ground level.

The technique involves removing vegetation at periodic intervals and drying the samples to a constant weight. To obtain an accurate estimate the production of plant biomass is sampled throughout the growing season and the contribution of each species is determined. Different species of plants reach their peak production at different times during the growing season. The difference in standing crop biomass between harvests periods expressed as grams per square meter per unit time provides an estimate of net primary productivity. Caloric value of the material can be determined through use of a calorimeter and biomass can be converted to calories. Net primary productivity is then expressed as kilocalories per square meter per year.

Harvest method provides information about above ground productivity usually because low ground productivity requires the samples of root biomass.

In this method the plants grown on a particular field are clipped at ground level and their weight is taken. This is done at periodic intervals. After drying to constant weight the harvest is then expressed in terms of biomass or mass per unit area per unit time (the unit of mass= gram, unit of area=meter, and unit of time =year). If the exact caloric content of the material is known the biomass can easily be converted and expressed in terms of energy.

6.3 REQUIREMENTS:

- Metric scale
- Scissors
- Plougher or a weeding instrument
- Grass seeds
- Collection boxes
- Polythene bags
- Digital Weighing balance
- Oven
- Soil
- Empty pot or empty clean two-liter bottle
- Tissue paper

6.4 PROCEDURE

The primary productivity of one week of grass growth using two methods: complete plant *removal* and *clipping*.

Field method

1. Take an appropriate size quadrat or make an area of say 1×1 m2 in the grass field.
2. Carefully remove the entire grass plants from the soil (complete plant removal method) or measure a fix length of grass from the topsoil and cut it (Clipping method).

3. If whole plant is removed, remove as much soil as possible, but try to keep all the roots, they are part of the growth of the plant. Carefully rinse off any remaining soil from the roots by gentle shaking.
4. Place the plants on tissue paper or in a large beaker and keep them in the drying oven for seventy-two hours (3 days).
5. After the 3-day drying time, remove the samples from the drying oven and let them cool.
6. When cool, weigh the sample. This is the starting dry mass.
7. After one week of removal again take the sample in the same way as in step 2 and repeat the process.
8. After the 3-day drying time, remove the samples from the drying oven and let them cool. When cool, find the mass of each sample. This is the final dry mass.

Laboratory method

1. Fill an empty pot or cut-open two-liter bottle with soil.
2. Plant a handful of grass seeds in the soil.
3. Place a dampened tissue paper over the soil.
4. Allow the grass to grow; after it does so, use scissors and a ruler to cut it to a height of 2 cm.
5. After 13 days, use scissors and a ruler to cut the grass to a height of 2 cm as before.
6. Carefully remove all the grass clippings. Allow them to dry for at least 2 days before weighing them using a digital weighing balance.
7. Measure the area of the grass.
8. Record the data and calculate the net primary productivity (NPP) using the following formula: NPP = Biomass/Area/Day

6.5 OBSERVATION AND CALCULATIONS

Area of quadrat: _____ m^2

Number of days after which second sample is taken: _____days

Starting dry mass (S): _____ grams

Final dry mass (F): _____grams

Biomass: F-S = _____ grams

NPP: Biomass (in grams) ÷ Area (in m^2) ÷ number of days

6.6 RESULT

The net primary productivity (NPP) was found to be _____ grams/ m^2/day

6.7 PRECAUTIONS

1. While removing complete plant be careful not to harm the existing fauna
2. Be careful while handling the oven

EXPERIMENT 7

ESTIMATION OF NET PRIMARY PRODUCTIVITY USING LIGHT AND DARK BOTTLE METHOD IN AQUATIC ECOSYSTEM.

Primary production in a standing water ecosystem depends on the chemical nature of the basin, the nature of imports from streams or land and the depth of the water body. The chief physical, chemical and biological limiting factors to primary productivity are light, temperature, nutrients and zooplankton grazing. The measurement of primary productivity provides a photosynthetic integration of physical, chemical and biological conditions and if conducted overtime is an excellent measure of charge in the trophic state of an aquatic system. Phytoplanktons are the main producers of the aquatic ecosystem.

The primary production in the aquatic ecosystem starts with the synthesis of organic compounds from the inorganic constituents of water by the activity of plants / phytoplankton in the presence of sunlight. The inorganic constituents which form the raw material for this synthesis are water, carbon dioxide, nitrate ions, phosphate ions and various other chemical substances. The products are mainly carbohydrates and proteins and fats in very small quantities. Organic production by plants is the first step in tapping energy by living beings from non-living natural resources and hence called primary productivity. Gross Primary Productivity (GPP) is the total rate of photosynthesis including the organic matter used up in respiration during measurement period, while Net Primary Productivity (NPP) refers to the amount of organic matter that is stored in plant tissues after meeting the demand of respiration.

7.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain the primary productivity, net primary productivity NPP and gross primary productivity GPP
- Know about dissolved oxygen
- Know about photosynthetic quotient
- Calculate the NPP and GPP

7.2 PRINCIPLE

The method of estimating primary productivity by dark and light bottle method was introduced by Garder and Gran (1930). In this method, the water samples are incubated for a certain period in light and dark bottles which are then suspended at the same depths from where the samples are taken. In light bottles, oxygen is released as a result of photosynthesis and a part of oxygen is used for community respiration. In the dark bottles, only oxygen consumption takes place as a result of respiration. The amount of oxygen liberated by phytoplankton during photosynthesis is considered as a measure of primary production.

This method is based on the estimation of dissolved oxygen in the water samples (ml/l) by Winkler's method. Three BOD bottles are used for this purpose. The DO (dissolved oxygn) content in the control (C), Dark (D) and Light (L) bottles after specific incubation period are utilized to calculate the primary productivity. The incubation period varies with the nature of water sample such as 3.0 hours for sea water whereas 2.5 hours for shallow estuarine water. The incubation is done in light for the same in 'L' bottle and in dark 'D' bottle, while sample in C bottle is fixed by Winkler 'A' and 'B' at the initial stage of experiment.

7.3 REQUIREMENTS

Apparatus

BOD bottles (300 ml) 3 (2 transparent and 1 dark colored)

Beakers

Conical flasks

Measuring cylinder

Pipettes

Glass dropper

Burette

Burette stand

Analytical balance

Black sheet or aluminium foil

Chemicals

Maganous sulphate monohydrate ($MnSO_4.H_2O$)

Potassium hydroxide (KOH) or sodium hydroxide (NaOH)

Potassium iodide (KI) or sodium iodide (NaI)

Sodium thiosulphate (Na2S2O3 .5H2O)

Concentrated sulphuric acid (H_2SO_4)

Starch

7.4 PREPARATION OF SOLUTIONS

i. Winkler A solution (Maganous sulphate solution): Weigh 91.0 gm of maganous sulphate monohydrate ($MnSO4.H_2O$) and dissolve it in 250 ml distilled water.

ii. Winkler B solution (Alkali-iodide-azide reagent): Dissolve 175 g Potassium hydroxide (Or 125 g sodium hydroxide) and 37.5 g potassium iodide (or 33.7 g sodium iodide) in a little distilled water and dilute with distilled water upto 250 ml.

iii. Sodium thiosulphate solution (Hypo). Dissolve 24.82 g sodium thiosulphate in a little double distilled water in a volumetric flask. Dilute with distilled water upto 1000 ml. To make 0.025 N sodium thiosulphate solution, take 250 ml of 0.1 N sodium thiosulphate and dilute it to 1000 ml with double distilled water.

iv. Starch indicator solution: Take l gm starch in a little water. Make a thin paste and pour it in 100 cc boiling water. Keep on boiling for 2 minutes and then cool.

7.5 PROCEDURE

1. Filtered water samples through zooplankton filters (0.4mm mesh size) are preferred in Primary productivity experiments to minimise the interference of zooplankton and suspended particles.

2. Water samples are collected in plastic bucket and kept undisturbed for few minutes for uniform distribution of phytoplankton.
3. Label the BOD bottles as C "control" (transparent bottle), L " Light" (transparent bottle), and D "dark" (Dark bottle)
4. Collect water samples in BOD glass bottles without entangling air bubbles and close the lids gently.
5. Water sample in the C bottle is immediately fixed by using Winkler's fixatives and dissolved oxygen is estimated by Winkler method as given below:

a. Fixation:

i. Add 2 ml Winkler A solution in the bottle by pipette. The pipette should never touch the water level. It should always be above the water level.

ii. Now add 2 ml Winkler B solution.

iii. Stopper the bottle with care to be sure no air is introduced. Mix the sample by inverting several times. Check for air bubbles; discard the sample and start over if any are seen. If oxygen is present, a brownish-orange cloud of precipitate will appear. When this precipitate has settled to the bottom, mix the sample by turning it upside down several times and let it settle again. If white precipitate, no Oxygen. Allow the precipitate to settle completely.

iv. Add 2 ml of concentrated sulfuric acid via a pipette held just above the surface of the sample. Carefully stopper and invert several times to dissolve the floc. At this point, the sample is "fixed" and can be stored for up to 8 hours if kept in a cool, dark place. As an added precaution, squirt distilled water along the stopper, and cap the bottle with aluminum foil and a rubber band during the storage period.

B. Titration:

i. In a conical flask, titrate 201 ml of the sample with hypo to a pale straw color. Titrate by slowly dropping titrant solution from a burette into the flask and continually stirring or swirling the sample water.

ii. Add 2 ml of starch solution so a blue colour forms.

iii. Continue slowly titrating until the sample turns clear. As this experiment reaches the endpoint, it will take only one drop of the titrant to eliminate the blue color. Be especially careful that each drop is fully mixed into the sample before adding the next. It is sometimes helpful to hold the flask up to a white sheet of paper to check for absence of the blue color.

iv. The concentration of dissolved oxygen in the sample is equivalent to the number of milliliters of titrant used. Each ml of sodium thiosulfate added in steps 6 and 8 equals 1 mg/l dissolved oxygen.

6. The BOD bottle "D" is wrapped with aluminum foil and kept in a black bag to protect from light.
7. Suspend both L and D bottles exactly at the depth from where the sample was drawn
8. The bottles are normally incubated for a period of 30 minutes to 2 hrs
9. At the end of incubation period, the bottles are retrieved and fixed Winkler's fixatives.
10. The oxygen content in the sample is determined by using Winkler's method as above.

7.6 OBSERVATIONS AND CALCULATIONS

Observation table

S.No.	Bottle	Volume of hypo used (in ml)			Final volume of hypo used (in ml) average of 3 readings
		Initial reading (in ml) a	Final reading (in ml) b	Volume of hypo used (in ml) (b-a)	
1	Control	1.			O_C =
		2.			
		3.			
2.	Light	1.			O_L =
		2.			
		3.			
3.	Dark	1.			O_D =
		2.			
		3.			

Calculations:

Oxygen content in control = OC

Oxygen content in dark bottle = OD

Oxygen content in light bottle = OL

Net oxygen production = OL – OC

Oxygen consumed for respiration = OC – OD

Gross production of oxygen = OL – OD

Number of hours of incubation= t

Photosynthetic Quotient "PQ" (molecules of O_2 produced/molecules of CO_2 taken up)= 1.25

Conversion factor = 0.375 × 1000

Therefore the Primary productivity can be calculated from the formula

Gross primary productivity "GPP" (mg C/m3/hour) = $\frac{OL - OD \times 1000 \times 0.375}{PQ \times hrs}$

Net primary productivity "NPP" (mg C/m3/hour) = $\frac{OL - OC \times 1000 \times 0.375}{PQ \times hrs}$

7.7 RESULT

The gross primary productivity "GPP" was found to be _____ mg C/m3/hour.

The net primary productivity "NPP" was found to be _____ mg C/m3/hour.

7.8 PRECAUTIONS

1. Do not allow air to trap while sampling water during BOD analysis.
2. Dip the tip of the pipette just at the bottom of the BOD bottle and gently release the reagents.

3. Take care that the chemicals do not flow out from the bottle while shaking/ swirling.
4. Observe the colour changes during the BOD reaction, if any.

EXPERIMENT 8

ESTIMATION OF BIODIVERSITY INDICES

Biodiversity is defined as the degree of variability and heterogeneity amongst all the life forms at all levels in an ecosystem. The term biodiversity was coined by Walter G. Rosen in 1985. Measuring the biodiversity of a community or ecosystem helps us to understand the relationship between the members of that community and with the existing environmental conditions. Whittaker (1972) has described three levels of biodiversity: alpha α, beta β, and gamma γ. Alpha diversity refers to the diversity of species within a particular area/ habitat/ community/ecosystem. It is usually expressed by the number of species or the species richness. Beta diversity is the diversity of species between two or more ecosystem. Beta diversity measures the rate and extent of species change from one community to other. Gamma diversity is a broad term including the total diversity of species over a large geographic area.

Biodiversity of an area can be measured using different indices called as biodiversity indices. Biodiversity indices are mathematical measure of species diversity. They are based on the number of species i.e., species richness and the number of individuals per species i.e., abundance. These indices not only explain the richness of community but also give us information about the composition of community. These indices are easy to calculate and are widely used for various ecological assessments.

Species diversity or α-diversity is measured by many indices:

i. Shannon-Wiener diversity index (H)
ii. Simpsons' diversity index (D)
iii. Species richness (s)
iv. Relative Comparison Index (CI)
v. Margalef's diversity index
vi. Berger-parker index

As per Wilson and Schmida there are 6 indices to measure beta diversity:

i. Whittaker's βw
ii. Cody's βc
iii. Routledge's βR
iv. Routledge's βP
v. Routledge's βE
vi. Wilson and Schmida's βT

8.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Know about the concept of biodiversity
- Know about types of biodiversity
- Know about the biodiversity indices
- Calculate Shannon Wiener diversity index
- Calculate Simpson's diversity index

8.2 PRINCIPLE

Shannon-Wiener diversity index (H) and Simpsons' diversity index (D) are the most commonly used measures of species diversity. Shannon wiener Index gives an account of the relative abundance and evenness of a species in a habiat or community. It is represented by H and is also known as Shannon's diversity index, the Shannon–Wiener index, and the Shannon entropy. It was originally given by Claude Shannon in 1948.

Its measurement is based on two important aspects species richness and abundance. The index assumes that all species are represented in a sample, the sample is drawn randomly from a large community and the total number of species is known.

The Shannon index is calculated by the given formula:

$$H = -\sum_{i-1}^{s} P_i \ln P_i \qquad \text{where } P_1\ n_i / N$$

where

H is Shannon-Wiener species diversity.

P_i is the proportion (n_i /N) of individuals of one particular species found (n) divided by the total number of individuals found (N),

ln is the natural log,

Σ is the sum of the calculations,

ni is the total number of individual of species.

N is the total number of all species in stand.

S is the number of species in the sample.

It is interpreted that H increases as the number of species (i.e. richness) in the community increases but increasing the number of species in a community will not necessarily increase diversity. Shannon-Wiener diversity index is less sensitive to rare species.

Second common index is the Simpson index. It was given by Edward H. Simpson in 1949. The Simpson index is a dominance index as it focuses on the common or dominant species. It is also called as Simpson Yule index and is represented by D. It is given by the formula:

$$D = 1/\left[\sum_{i-1}^{s} (P_i)^2\right] \qquad \text{where } P_1\ n_i / N$$

where

D is Simpson index

Pi is the proportion (ni /N) of individuals of one particular species found (n) divided by the total number of individuals found (N),

Σ is the sum of the calculations,

ni is the total number of individual of species.

N is the total number of all species in stand.

S is the number of species in the sample.

Simpson's index ranges from 0 to 1.0. 0 shows that community complexity is less and 1 depicts that community complexity is high. Low diversity (near to 0) indicates presence of dominant species, high diversity (near to 1) indicates presence of all constituent species in an almost uniform state. Simpsons' index is most sensitive to the changes in the more abundant species.

8.3 REQUIREMENTS

Scale

Pegs

Thread

Pencils

Notebook

Log table

8.4 PROCEDURE

1. Collect the necessary data from the field by using quadrat method
2. Random sampling should be done.
3. Collect data in the table format as given
4. Calculate the Shannon Wiener index and Simpson's index from the formula given.

8.5 OBSERVATION AND CALCULATION

Observation table

S.No.	Species	No. of Species
1.	Species A	
2.	Species B	
3.	Species C	

Calculations

Calculate Shannon Wiener Index and Simpson index using the formula

8.6 RESULT

The Shannon Wiener Index was found to be_____ .

The Simpson index was found to be_____.

8.7 PRECAUTIONS

1. The sample should be collected randomly.
2. Try to collect all the species while sampling

III EXERCISES ON WEATHER AND CLIMATE ANALYSIS

EXPERIMENT 9

WEATHER MONITORING AND DATA ANALYSIS

Weather is used to describe the momentary atmospheric conditions at a certain place. It is the state of the atmosphere of a given place at a particular time. Weather describes the condition of the atmosphere over a short period of time. The study of weather is as old as the creation itself; it has always had a significant influence on mankind. Man has always tried to find out the causes of different weather conditions and possibly monitor and predict what the weather would be at any given time. Taking weather and trying to forecast it appropriately can make a difference for the survival and prosperity of the human race. Weather is mostly influenced by the following factors:

i. Location (latitude)

ii. Elevation

iii. Proximity to water bodies

The periodic or continuous surveillance or analysis of the state of the atmosphere and climate, including variables such as temperature, moisture, wind velocity and barometric pressure is called weather monitoring.

Weather monitoring is of great significance and has uses in several areas ranging from keeping track of agricultural field weather conditions to industrial weather conditions monitoring. Weather measuring and monitoring also helps in keeping track of different atmospheric and climatic parameters like temperature, humidity, atmospheric pressure, light intensity rainfall, wind speed and wind direction. The knowledge of the prevailing conditions of the atmosphere is pre requisite for studying weather.

In describing the atmospheric conditions of a given place at a given time, certain weather elements or parameters must be known, measured and quantified. Some of the most crucial weather elements are temperature, relative humidity, atmospheric pressure, wind speed and direction, precipitation, solar and light intensity. Temperature is a widely measured variable and is a very critical factor in determining the weather; because it influences and controls other elements of the weather

Modern weather monitoring systems and networks are designed to make the measurements necessary to track these movements in cost effective manner. Temperature and humidity are indicated for both indoor and outdoor location. Programmable alarms are also available in the monitoring system which indicates out of range condition.

The space-based weather monitoring system or station consist of two major components. The satellite with its data collection sensors and the data processing system. The data processing system is responsible for requesting (from the satellite) data that must be collected and scheduling the task need to be executed. Weather monitoring is very much helpful to the farmer to monitor weather parameters at their farms. This is also helpful for the industrial processes, ultimately the weather monitoring holds the great importance and having positive impact on the society.

9.1 OBJECTIVES

After doing this exercise, you must be able to:

- Know the concept and principle of weather monitoring
- Explain the various components of weathering monitoring station
- Collect the data for weather forecasting.

9.2 PRINCIPLE AND CONCEPT

A weather station is a facility, either on land or sea, with instruments and equipment for measuring atmospheric conditions to provide information for weather forecasts and to study the weather and climate.

An automatic weather station (AWS) is an automated version of the traditional weather station, either to save human labour or to enable measurements from remote areas. An AWS will typically consist of a weather-proof enclosure containing the data logger, rechargeable battery, telemetry (optional) and the meteorological sensors with an attached solar panel or wind turbine and mounted upon a mast. The specific configuration may vary due to the purpose of the system. The system may report *in near real* time via the Argos System and the Global Telecommunications System, or save the data for later recovery.

In the past, automatic weather stations were often placed where electricity and communication lines were available. Now a days, the solar panel, wind turbine and mobile phone technology have made it possible to have wireless stations that are not connected to the electrical grid or hardline telecommunications network.

Parameters of Weather Station

Temperature: A temperature is an objective comparative measure of hot or cold. Temperature usually measured by the thermometer. Several scales and units are available for the temperature. Most common is Celsius (^{0}C formally known as centigrade), also measures in Fahrenheit (^{0}F) and Kelvin (^{0}K) 1 K = 273+ ^{0}C and 1 F= 32 + 9/5^{0}C.

Humidity: The amount of water vapor in the air is known as humidity. Water vapor is the gaseous state of water and is invisible *Relative humidity measures in % Absolute humidity* $\Delta H = mH_2O/Vnet$ mH_2O = mass of water vapor. Vnet =Volume of air and water vapor mixture.

Atmospheric pressure: The pressure exerted by the weight of air in the atmosphere of the earth. The force over the one centimeter is a pressure of 10.1 N/m^2. 1 milli bar = 1hecto Pascal At sea level = 101325 Pascal or 101.325 hecto Pascal.

Light intensity: There are several measures of the *light are commonly known as intensity*. A photometric quantity measured in the lumens per steradian (lm/sr) or candela is known as luminous intensity. The SI unit of the illuminance measuring luminous flux per unit are is lux. 1 Lux = 1 Lumen per square meter.

Rainfall: Rain is the liquid water in the form of droplets that condenses from atmospheric water vapor and *the precipitated that is become heavy* enough to fall under gravity. Raindrops have sizes of 0.1 to 9 mm diameter above which they tends to break up. Rainfall is measured in the millimeter/24 hours.

Wind: Wind is a flow of the gaseous on a large scale on the surface of the earth. Wind consist of bulk movements of the air. Wind speed are usually calculated in meter/second or kilometer/hour. 1 m/sec = 2.237 miles/hour = 3.60 km/ hour.

There are two types of the weather monitoring approaches:

1. Traditional Approach/ Manual Approach
2. Modern Approach

1. Traditional Approach/ Manual Approach

There are many methods which are helpful to calculate the weather parameters. Manual methods need to take the readings at the place of the station by human being. This method of traditional approach is accurate and depend on the person who takes the values. Before going for any method we must know the definitions and standard unit of the weather parameters. A manual inventory system relies heavily on the action of the people which increases the possibilities of human error. In human error people might forget to record the weather parameters or simply make mistake in writing any value. This can affect the systems integrity. The time taken for sensing this types of analog instruments is very much hence it also cause the error. As far as the accuracy is concerned this system is less accurate than now days digital system.

Parameters	Instrument Used	Range	Difficulties
Temperature	Thermometer	-35 °C to + 55°C	Need to take readings manually
Humidity	Dry bulb and Wet bulb	10% to 80%	Reading are not accurate
Rainfall	Cylindrical jar and conical flask	10 mm to 250 mm	Need to calculate value manually
Wind Velocity	Anemometer	Max 74 m/sec	
Wind Direction	Arrow like structure		Direction decided by observing

Table 9.1: Brief details about the traditional approach of weather monitoring

Disadvantages:

i. Readings need to take manually by human causes human error.
ii. Sensing time is very high.
iii. High installation cost.
iv. Complex installation.
v. Hard to replace any elements

2. Modern Approach

Meteorological parameters are measured by using an automated weather station using sensors without intervention of humans. The measured parameters can be stored in a built-in data logger or can be transmitted to a remote location via a communication link. The data is stored in a data logger. The recorded data can be physically downloaded to a computer at a later time for further processing. The communication system is an essential element in an automated weather station. Now-a-days wireless technology is rapidly increasing and also used to monitor weather parameters remotely. Instead of analog instruments now a day we can use with internally calibrated. In addition with above all features sensing time is very less hence digital method is advantageous. The system design consist of transmitter as well as receiver. Transmitter section consist of different types of sensing units such as temperature measurement, Humidity measurement, Atmospheric pressure measurement, Air quality measurement, Rainfall measurement, Wind speed and wind direction measurement. The output

can be shown on either LCD or Computer Monitor. In case of the wired system output is usually displayed on the Liquid crystal display, while using wireless protocol output is shown on the computer monitor at remote place.

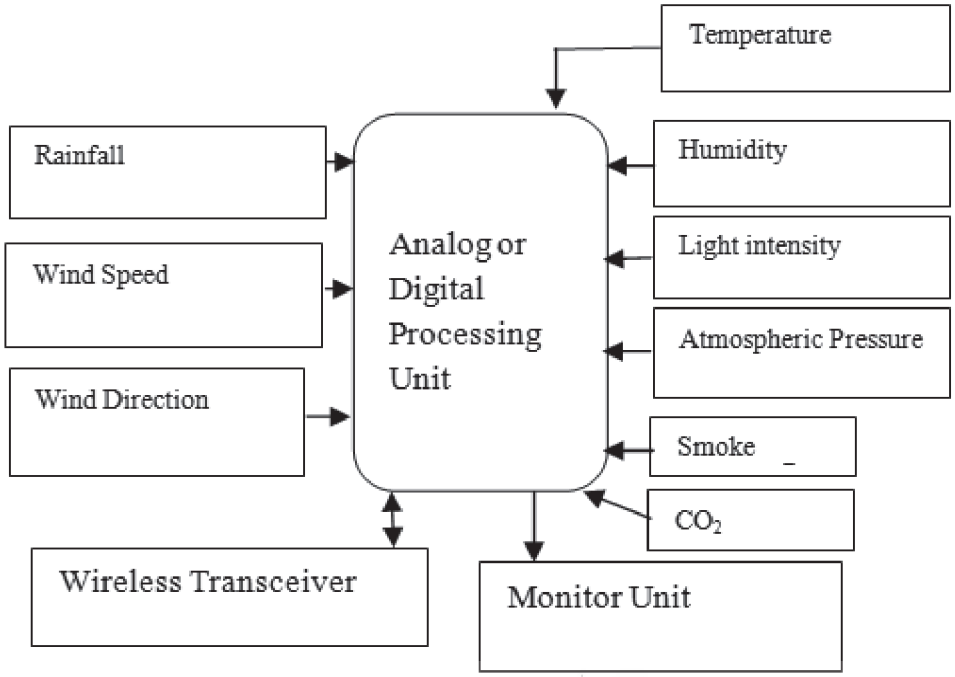


Figure 9.1: Block Diagram of Weather Monitoring Station

Components of Monitoring System

There are two main components

1. Microcontrollers 2. Sensors

1. Microcontrollers

These are compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip. A microcontroller is embedded inside of a system to control a singular function in a device. It does this by interpreting data it receives from its I/O peripherals using its central processor. The temporary information that the microcontroller receives is stored in its data memory, where the processor accesses it and uses instructions stored in its program memory to decipher and apply the incoming data. It then uses its I/O peripherals to communicate and enact the appropriate action.

Thus, microcontrollers assist in

- Measurement and collection of all the information from every sensor and archives it. It processes most of the meteorological data for the users (avg, min, max...).
- Storing all the data either on its own memory or on SD memory card.
- Managing the power supply of the Automatic Weather Station, using a solar panel for instance.
- Managing the communication protocols with the remote server.

Sensors

Sensor is a device which gives an output by detecting the changes in quantities or events can be defined as a sensor. Generally, sensors produce an electrical signal or optical output signal corresponding to the changes in the inputs. There

are different types of sensors, for example, consider a thermocouple which can be considered as temperature sensor that produces an output voltage based on the input temperature changes. Sensors are sophisticated devices that are frequently used to detect and respond to electrical or optical signals. A Sensor converts the physical parameter (for example: temperature, blood pressure, humidity, speed, etc.) into a signal which can be measured electrically. The mercury in the glass thermometer expands and contracts the liquid to convert the measured temperature which can be read by a viewer on the calibrated glass tube.

Types of sensors:

i. Temperature Sensor

ii. Humidity and Temperature Sensor

iii. Light intensity sensor

iv. Pressure Sensor

v. Wind vane sensor

vi. IR Sensor

vii. Ultrasonic Sensor

viii. Proximity Sensors

ix. Level Sensors

x. Smoke and Gas Sensors

xi. Touch Sensor

i. Temperature Sensor

Temperature is one of the most commonly measured environmental quantity for different reasons. There are different types of temperature sensors that can measure temperature, such as thermocouple, thermistors, semiconductor temperature sensors, resistance temperature detectors (RTDs), and so on. Based on the requirement, different types of sensors are used for measuring temperature in different applications.

ii. Humidity and Temperature Sensor

DHT11 is a Humidity and Temperature Sensor, which generates calibrated digital output. DHT11 can be interface with any microcontroller like Arduino, Raspberry Pi, etc. and get instantaneous results. DHT11 is a low cost humidity and temperature sensor which provides high reliability and long term stability.

iii. Light intensity Sensor

A Light Dependent Resistor is a device which has a resistance which varies according to the amount of light falling on its surface, when light falls upon it then the resistance changes. Light dependent resistors or LDRs which is used to detect the presence of light, or the ambient level of light, often to create a light triggered switch.Different LDR's have different specifications. LDR circuit is very easy to use. LDRs are made from semiconductor materials to enable them to have their light sensitive properties.

iv. Pressure Sensor

A pressure sensor is a device for pressure measurement of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.

v. Wind vane Sensor

Here we are using a potentiometer based wind vane mechanism for calculating the direction from which the wind is coming towards the station. The minimum angle of the wind vane sensor we are using here is 220 - 230, which is sufficient. We can also increase the resolution of the wind vane sensor if desired.

vi. IR Sensor

The small photo chips having a photocell which are used to emit and detect the infrared light are called as IR sensors. IR sensors can be used for detecting stacles of robotic vehicle and thus control the direction of the robotic vehicle. There are different types of sensors which can be used for detecting infrared lights.

vii. Ultrasonic Sensor

A transducer that works on the principle similar to the sonar or radar and estimate attributes of the target by interpreting is called as ultrasonic sensors or transceivers. There are different types of sensors that are classified as active and passive ultrasonic sensors that can be differentiated based on the working of sensors.

viii. Proximity Sensors

A proximity sensor often emits an electromagnetic field or a beam of Electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.

ix. Level Sensors

Level sensors detect the level of liquids and other fluids and fluidized solids, including slurries, granular materials, and powders that exhibit an upper free surface. Substances that flow become essentially horizontal in their containers (or other physical boundaries) because of gravity whereas most bulk solids pile at an angle of repose to a peak. The substance to be measured can be inside a container or can be in its natural form (e.g., a river or a lake). The level measurement can be either continuous or point values. Continuous level sensors measure level within a specified range and determine the exact amount of substance in a certain place, while point-level sensors only indicate whether the substance is above or below the sensing point. Generally the latter detect levels that are excessively high or low.

X. Smoke and Gas Sensors

A smoke detector is a device that senses smoke, typically as an indicator of fire. Commercial security devices issue a signal to a fire alarm control panel as part of a fire alarm system, while household smoke detectors, also known as smoke alarms, generally issue a local audible or visual alarm from the detector itself.

xi. Touch Sensor

Touch sensors can be defined as switches that are activated by the touch. There are different types of touch sensors that are classified based on type of touch such as capacitance touch switch, resistance touch switch, and piezo touch switch.

Other sensors may be present like:

- Ceilometer for measuring cloud height
- Present weather sensor and/or visibility sensor
- Rain gauge for measuring liquid-equivalent precipitation

- Ultrasonic snow depth sensor for measuring depth of snow
- Pyranometer for measuring solar radiation

IoT

Internet of Things is the latest analytics system which should be used for sensing, networking,big data, and artificial intelligence technology to deliver complete information of the systems for a product or service. These systems allow greater transparency, control, and performance when applied to any industry or system. IoT systems have lot of applications across in the world because of their unique flexibility and ability to be suitable in any kind of the environment. They enhance data collection, automation, operations, and much more through smart devices and powerful enabling technology. IoT systems have a capability to achieve automation, analysis, and integration within that system, which should be improving the reach of these areas and their accuracy. IoT utilizes existing and emerging technology for sensing, networking, and robotics. IoT exploits recent advances in software, falling hardware prices, and modern attitudes towards technology. Its new and advanced elements bring major changes in the delivery of products, goods, and services; and the social, economic, and political impact of those changes.

The weather monitoring system is designed in such a way that it can be used remotely and the readings are displayed on the user friendly LCD display in numerical digital values and can also be sent to computer via the programmed micro SD card or through the serial port

There are several options available for retrieving the data from the AWS:

- Data can be manually transferred from the logger to a laptop via a download cable.
- Alternatively, a modem built into the weather station allows you to remotely retrieve the data.
- Weather data can be viewed on the internet with the information displayed on a public or private website

Thus, weather monitoring and data analysis are an important part to predict and forecast weather conditions and prepare for the calamities well inadvance.

EXPERIMENT 10

PREPARATION OF A CLIMATIC MAPS AND DIAGRAMS

The climate of a region can be defined as a dominant and recurring weather pattern occurring in one geographical area over a long period of time. It is measured by assessing variables such as humidity, precipitation, temperature, atmospheric pressure, and wind. Climate is different from weather in that weather is a measure of the above variables over a short period of time. Regions around the globe are divided into climate zones, sometimes known as the Koppen climate classification. The various zones can be represented on a sheet of paper or flat surface by a climate map.

A climate map is a graphical representation of the distribution of the prevailing weather patterns in a given area that has been observed over a long period. Climatic maps are special type of maps which show the geographic distribution of the monthly or annual average values of climatic variables—i.e., temperature, precipitation, relative humidity, percentage of possible sunshine, insolation, cloud cover, wind speed and direction, and atmospheric pressure over regions ranging in area from a few tens of square kilometres to global.

Climatic maps can be compiled both for individual climatic features (temperature, precipitation, humidity) and for combinations of them at the earth's surface and in the upper layers of the atmosphere. They generally apply to individual months and to the year as a whole, sometimes to the four seasons, to the growing period, and so forth. On maps compiled from the observations of ground meteorological stations, atmospheric pressure is converted to sea level. Air temperature maps are compiled both from the actual values observed on the surface of the earth and from values converted to sea level. The pressure field in free atmosphere is represented either by maps of the distribution of pressure at different standard altitudes—for example, at every kilometer above sea level—or by maps of baric topography on which altitudes (more precisely geopotentials) of the main isobaric surfaces (for example, 900, 800, and 700 millibars) counted off from sea level are plotted. The temperature, humidity, and wind on aeroclimatic maps may apply either to standard altitudes or to the main isobaric surfaces.

Climatic maps afford a very convenient overview of the climatic features in a large region and permit values of climatic features to be compared in different parts of the region. Through interpolation the maps can be used to determine the values of climatic features in any particular spot. Climatic maps are often incorporated into climatic atlases of varying geographic range (globe, hemispheres, continents, countries, oceans) or included in comprehensive atlases. Besides general climatic maps, applied climatic maps and atlases have great practical value. Aeroclimatic maps, aeroclimatic atlases, and agroclimatic maps are the most numerous.

Climatic maps are used for references in the weather office, for geographical surveys, studies and research works about the climate change etc. Interactive climate maps are available online. Most of these maps are animated and show historical or projected weather changes in a given area. The interactive climate maps are extremely useful as they enable one to find specific climate information about an area.

10.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Distinguish between climate and weather

- Understand the concept of climatic maps and diagrams
- Understand the importance of climatic maps and diagrams

10.2 PRINCIPLE

Climatic maps reflect the territorial distribution of climatic conditions based on the results of long-term observations. Climate maps can represent the climate of a region, continent or the entire world. They use a combination of precipitation, temperature, seasonal variations and geographic features to identify climate zones. The map can represent an individual climatic variable or a combination of all the variable. A climate map provides an overview of the climatic features over a large region and allows for the comparison of the climatic features in different regions. It can represent the climate of a country, region, continent, or the entire globe. The maps also help scientists to track and illustrate climate change in different regions.

Climate maps are overlaid with colors representing the different climatic zones. There are no standard or specific color for each climate zone as long as different colors are used to differentiate climate zones within the same area. In addition to colors, letter codes are also used to specify differences among zones. Isolines are drawn on the maps to connect points with equal long term mean values of a climatic variable (temperature, atmospheric pressure, and humidity).

Mapping of the Climatic Data: Much of the climatic data is represented by line symbols. The most common of these are the isometric lines or isolines. These lines are depicted on the map as isopleths. The Isopleth can be interpolated for places having the same mean values of temperature, rainfall, pressure, sunshine, clouds, etc.

Isolines are drawn on maps of such climatic features as the long- term mean values (of atmospheric pressure, temperature, humidity, total precipitation, and so forth) to connect points with equal values of the feature in question—for example:

Isobars are lines connecting places of equal air pressure.

Isotherms are lines connecting places of equal temperature.

Isohyets are lines connecting places of equal amount of rainfall over a given period of time.

Isohels are lines connecting places of same mean daily duration of sunshine.

Isonephs are lines connecting places of same mean value of cloud cover.

Isoamplitudes are drawn on maps of amplitudes (for example, annual amplitudes of air temperature—that is, the differences between the mean temperatures of the warmest and coldest month).

Isanomals are drawn on maps of anomalies (for example, deviations of the mean temperature of each place from the mean temperature of the entire latitudinal zone). Isolines of frequency are drawn on maps showing the frequency of a particular phenomenon (for example, annual number of days with a thunderstorm or snow cover).

Isochrones are drawn on maps showing the dates of onset of a given phenomenon (for example, the first frost and appearance or disappearance of the snow cover) or the date of a particular value of a meteorological element in the course of a year (for example, passing of the mean daily air temperature through zero).

Isolines of the mean numerical value of wind velocity or isotachs are drawn on wind maps (charts); the wind resultants and directions of prevailing winds are indicated by arrows of different length or arrows with different plumes; lines of flow are often drawn. Maps of the zonal and meridional components of wind are frequently compiled for the free atmosphere. Atmospheric pressure and wind are usually combined on climatic maps. Wind roses, curves showing the distribution of other meteorological elements, diagrams of the annual course of elements at individual stations, *and the like* are also plotted on climatic maps.

A climate map is a depiction of prevailing weather patterns in a given area. It usually consists of a conventional map overlaid with colors representing climate zones. The map's legend helps you identify each zone.

To measure the different parameters different instruments are used as shown in Table 10.1

Table 10.1: Instruments for Measuring Weather Elements

S. No	Element	Instrument	Unit
1	Temperature	Thermometer	°C/°F
2	Atmospheric Pressure	Barometer	Millibars
3	Wind (Direction)	Wind Vane	Cardinal points
4	Wind (Velocity)	Anemometer	Km/hr
5	Rainfall	Rain Gauge	mm/cm

All these observations are recorded at fixed period of times i.e., hours, days, weeks, months and years at the weather stations and are compiled to form a climatic data of the region. Since the inception of the Indian Meteorological Department, the weather maps and charts are prepared regularly. Meteorological observatories transmit the daily data to the Central Observatory at Pune twice a day. Data is also collected on ships plying on the Indian seas.

As the data received from various weather observatories are in plenty and detailed, they cannot be incorporated in one single chart so special codes or symbols are used for expression. These are called meteorological symbols. Thus, the messages received from all the observatories are plotted on the map using weather symbols standardised by the World Meteorological Organisation and the National Weather Bureaus. (Figure10.2 and 10.3)

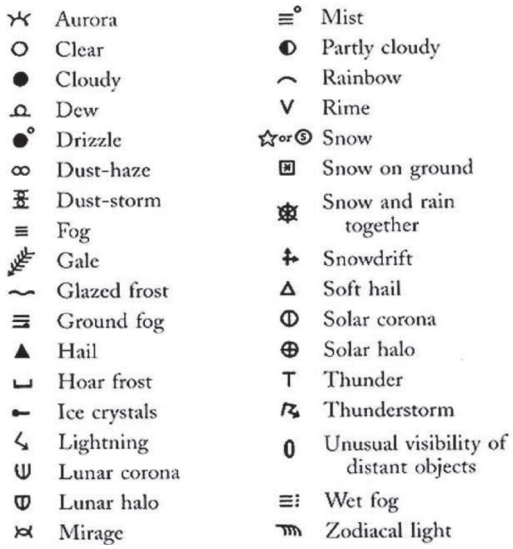


Figure: 10.2: Meterological Symbols

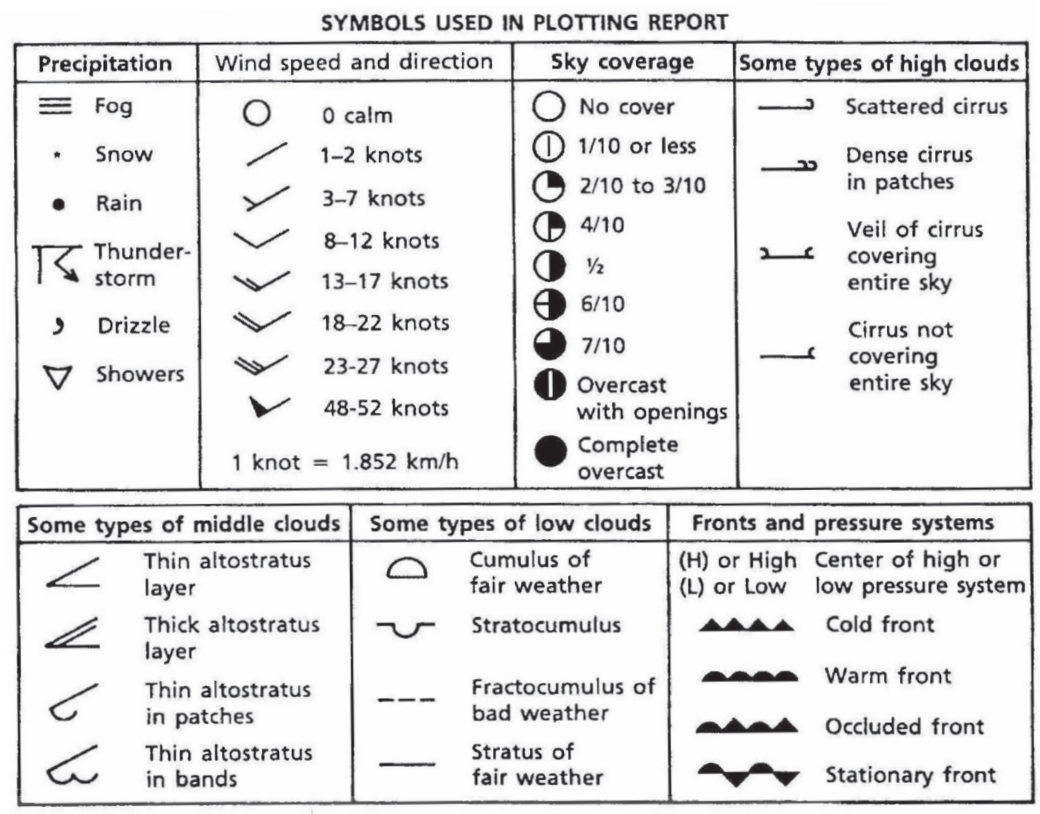


Figure 10.3: Different types of symbols used in climatic and weather maps

Climate graphs: Climate graphs are used to illustrate the average temperature and rainfall experienced at a particular place over the course of a year. The graphs consist of a red line graph showing average monthly temperature, and a simple column graph showing average monthly rainfall figures. Rainfall is, by tradition, shown in blue.

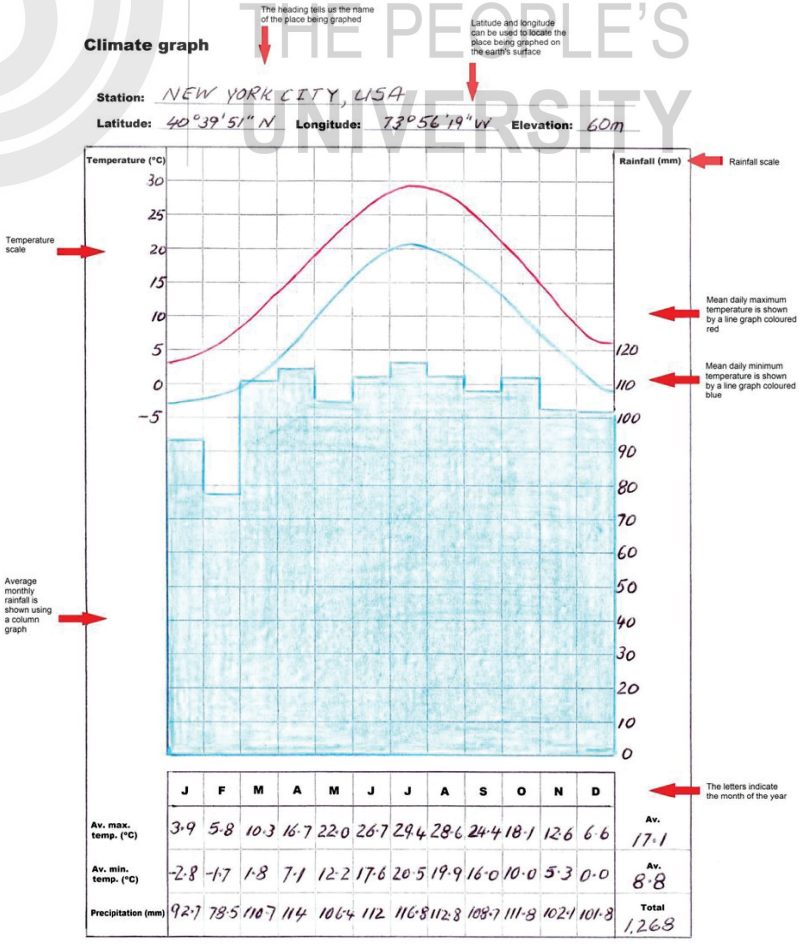


Figure 10.4: Hand-drawn climate graph of New York City

10.3 REQUIREMENTS

- Rainfall and temperature data
- Scale
- Notebook
- Graph paper
- Pencils
- Color pens

10.4 PROCEDURE

1. To construct a climate graph, use the climate graph template and follow the steps below.
2. Select a rainfall and temperature data of a year for a particular place alongwith the details of latitude, longitude etc as in figure 10.4.
3. Transfer the temperature and rainfall data from your data source into the table at the base of the climate graph as shown in Figure 10.4.
4. Locate the wettest month and the months with the highest and lowest temperatures. Use this information to add a suitable scale for both temperature and precipitation (rainfall). Place temperature scale on the graph's left-hand axis and rainfall on the right-hand axis.
5. Plot the rainfall figures. Then colour the columns blue.
6. Plot the average maximum and minimum temperature data, making sure each dot is placed in the centre of the month. Use a red pen or pencil to join the points plotted for the average maximum temperature with a smooth, red curve. Use blue for the line joining the points marking the lowest monthly temperature.
7. Add a heading that includes the name of the place being graphed and its latitude, longitude and elevation.

10.5 RESULT

The climatic graph shows detail of rainfall and temperature of the area over a period of one year.

NOTE: you can also interpret the colored climatic maps of different countries and if data available you can draw these climatic maps

EXPERIMENT 11

PREPARATION OF THE STATION BASED WIND ROSE FOR AN AREA

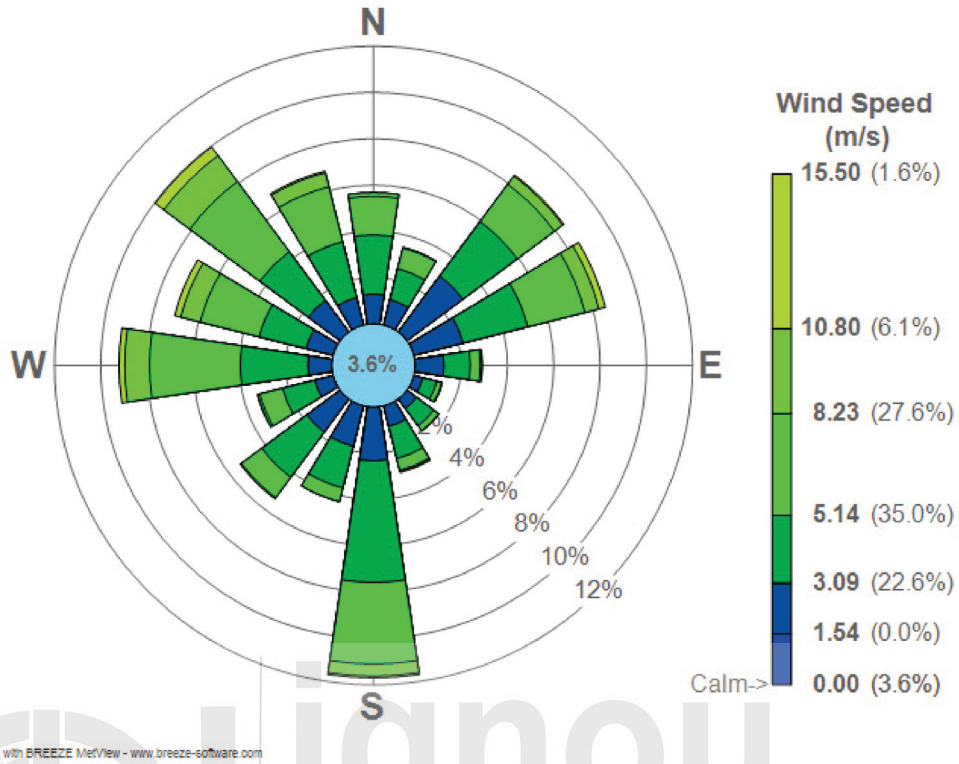


Figure 11.1: A typical wind rose diagram. Concentric circles represent frequency or percentage of time and color bar represents wind speed

A diagram which gives information about the wind speed and direction at a particular location over a specified period of time is called a wind rose. The wind rose is generally located in the top right corner of each data map showing the general wind direction and speed for each sampling period. The circular format of the wind rose shows the direction the winds blew from and the length of each "spoke" around the circle shows how often the wind blew from that direction (Figure 11.1). This wind rose usually has eight radiating lines, whose lengths are proportional to wind frequency, and shows wind strength by the thickness of the lines or by feathers attached to them. The frequency of calm or nearly calm air is given as a number in the centre. The important directions are (Figure 11.2):

- N (North), S (South), E (East) & W (West) represent the four cardinal directions.
- NE (North- East), SE (South- East), NW (North- West), SW (South-West) represent the four intercardinal directions.
- NNE (North North –east), ENE (East North-East), ESE (East South-East), SSE (South South-East), SSW (South South-West), WSW (West South-West), WNW (West North-West), NNW (North North-West) represent the 8 secondary intercardinal directions.

Before the use of magnetic compasses, a wind rose was used as a guide by mariners which helped them to know the directions of the eight principal winds. The modern wind rose used by meteorologists gives the percentage of the time the wind blows from each direction during the observation period; it sometimes shows the strengths of these winds and the percentage of the time calm air or light winds are observed.

The wind rose is a useful representation as large quantity of details is summarized in a single plot. Generally, 8 points of compass are used to record the direction of wind and to get more accuracy 16 or 32 points are used.

Wind rose diagram is used to depict the wind direction and average frequency for a particular site. Wind data are generally collected at 10 m above ground and if required at various height for specific purposes. They can be prepared for month-wise, season-wise or yearly as needed. Other data like wind velocity, air temperature etc. can also be included for detailed information. Wind rose diagram is vital for constructing runways in airports which are generally oriented towards the prevailing wind direction. It is also an important part of pilot and sailing charts. It is used by builders and architects for giving proper ventilation in buildings.

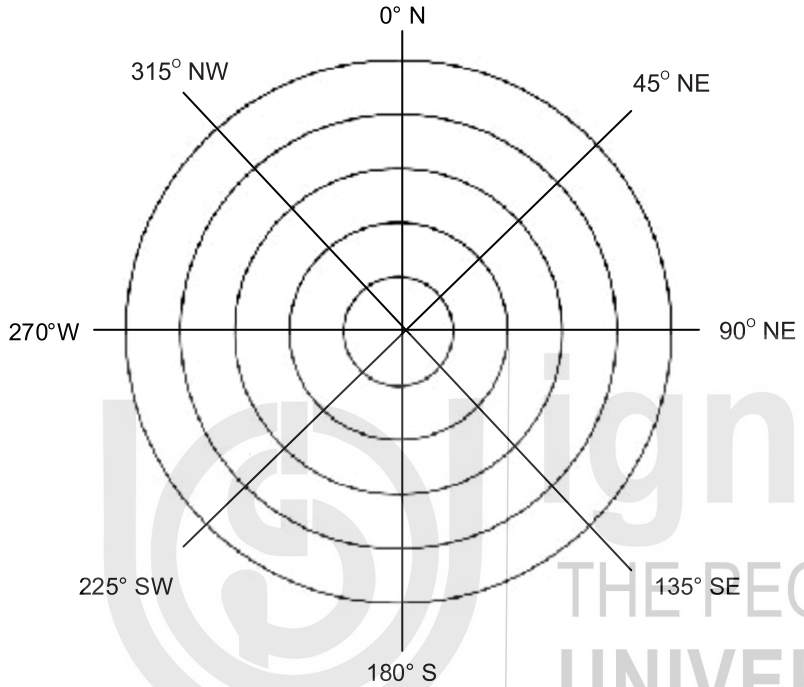


Figure 11.2: Concentric rings of wind rose and the directions

11.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Know about wind rose diagram
- Know the uses of wind rose
- Draw a wind rose manually

11.2 PRINCIPLE

The modern wind rose shows the frequency of winds blowing from particular directions over a specified period and is presented in a circular format. As already mentioned, the length of each "spoke" around the circle is related to the frequency that the wind blows from a particular direction per unit time.

By using polar coordinate system of gridding, the frequency of winds over a long time period is plotted by wind direction, with color bands showing wind ranges. The directions of the rose with the longest spoke show the wind direction with the greatest frequency. In a wind rose diagram (Figure 11.2):

Concentric circles represent percentage of time.

The numbers around the outside edge of the circle represent compass points showing the 16 directions.

The colour bars of the wind rose refer to the speed of the wind in miles per hour (mph).

11.3 REQUIREMENTS

Compass

Pencils

Colored pens/pencils

Protractor

11.4 PROCEDURE

1. To draw a wind rose diagram you require data of the station in the form of direction and percentage of days the wind blowing in that direction (as given in observation). After you get the data follow these steps:
2. Select a suitable scale for e.g. 1 cm = 10%
3. Draw a circle with this scale (1cm =10%) to represent the calm. For e.g. If the calm is 5% then draw a circle with 0.5 cm radius.
4. Mark the directions in this circle using a protractor keeping 0° for north, 45° for NE, 90° for East, 135° for South east, 180° for South, 225° for South west, 270° for West and 315° for North west.
5. Draw a bar of suitable length calculated from the scale in each direction as per the data given. For example, if the % of days of wind blowing is 28 in north direction and 7 in south direction then draw a bar of length 2.5 cm in northern direction and 0.7 cm in southern direction and so on for all the 8 or 16 directions as per the data.
6. On the wind rose mention the calm in the centre, the scale chosen to draw the diagram on the top right corner and name the directions on the windrose alongwith the angles.

11.5 OBSERVATION TABLE

Wind Direction	Percentage of days the wind blowing in this direction	
	Station 1	Station 2
N (North)		
S (South),		
E (East)		
W (West)		
NE (North- East),		
SE (South- East),		
NW (North- West),		
SW (South-West)		
Calm		

11.6 RESULT

Draw a labeled wind rose diagram.

11.7 PRECAUTION

1. Note that the total of each station should be 100%.
2. Mark the angles and percentage properly in the diagram.

EXPERIMENT 12

AERIAL PHOTOGRAPH INTERPRETATION

Photographs taken with normal cameras give us a horizontal perspective of the objects photographed i.e., the object similar to the way we see them with our own eyes. The photographs taken from an aircraft or helicopter using a precision camera are termed aerial photographs. The aerial photographs give a very different perspective, the bird's eye view, which is termed as aerial perspective. The aerial photographs are one of the most effective tools that can be used for the interpretation of the landscape.

The use of aerial photographs has many benefits:

- **Naturality:** When a scene is being viewed through an aerial photo, there is an immediate feeling of "naturalness", for the images can be intuitively understood by the observer
- **Improved vantage point:** Aerial photography provides a bird's eye view of large areas, enabling us to see features of the earth surface in their spatial context.
- **Historic record:** An aerial photograph is a record of the surface features at an instance of exposure. Thus, it has a time freezing ability and it can, therefore, be used as a historical record.
- **Extended Sensitivity:** The sensitivity of the film used in taking aerial photographs is relatively more than the sensitivity of the human eyes. the sensitivity of the film ranges from 0.3 to 0.9 μm whereas human eyes perceive only in the visible region i.e., 0.4 to 0.7 μm
- **Three-Dimensional Perspective:** Aerial photographs are normally taken with uniform exposure interval that enables us in obtaining stereo pair of photographs. Such a pair of photographs helps us in getting a three-dimensional view of the surface photographed
- The topographic map is the result of a selective process with symbols representing selected real-world features. Many facets of the landscape have to be omitted. This selectively is achieved at the expense of complex reality which is the forte of aerial photography
- **Human error free:** Aerial Photographs do not suffer from problems of human error in the way that maps sometimes do.

Whereas maps have symbols with an established meaning, aerial photos have different tones and patterns which must be distinguished and given a meaning by the interpreter.

12.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Know details and benefits about aerial photograph
- Know the principles involved in aerial photogragh interpretation
- Interpret the aerial photographs
- Determine scale in aerial photograph

12.2 PRINCIPLE

Image Interpretation: It is an art of identifying images of objects and judging their relative significance. Aerial photo interpretation is a method of studying terrain by examining aerial photographs of it. It involves detection and identification of the objects photographed, determination of their qualitative and quantitative characteristics, and recording the results graphically (using standard symbols), numerically, and textually. Aerial photo interpretation has certain features typical of terrain study in general, as well as certain differences, determined by the nature of the fields (practical and scientific) in which it is used (in combination with other methods of research).

Thus, the principles of aerial image interpretation are applied to obtain qualitative information from the aerial photographs such as land use/land cover, topographical forms, soil types, etc. A trained interpreter can thus utilize aerial photographs to analyze the land-use changes.

General rules for photographic interpretation:

In general photographs should be interpreted from the whole to the part, i.e. broad distinctions defined first. Interpretation should be approached systematically:

i. A literature review is a necessary part of any study and as much information as possible should be obtained from these sources;

ii. The photograph should be orientated. This may be possible with the aid of shadows. Many air photographs are taken near mid-day for optimum light conditions resulting in the shadows pointing between north-east and north-west in the northern temperate latitudes;

iii. A pattern or shape should be selected on the photograph which will be easily identified on the line map, e.g., coastline. An apparent match should be confirmed by supporting evidence;

iv. Photographic "keys" or file photos of significant features are extremely useful as aids to current investigation and as "memory joggers" in complex situations.

The interpretation of aerial photographs includes three major steps:

i. Examination of photographs to get a three-dimensional perception,

ii. Identification of ground conditions by observing certain elements appearing in the photographs, and

iii. Interpretation of photographs with respect to specific problems by association of ground conditions with one's background experiences.

Just like using normal vision "on the ground" an object can be distinguished by a combination of the three processes of observation i.e., size and shape; colour; and features with which it is associated. Similarly, eight fundamental parameters or clues are used to distinguish features and interpret the aerial photographs. They are as follows:

1. Size
2. Shape
3. Tone
4. Texture
5. Shadow

6. Pattern
7. Site
8. Associated features

1. **Size:** The size of objects can be important in discrimination of objects and features (cars vs. trucks or buses; bushes vs. trees, etc.). In the use of size as a diagnostic characteristic both the relative and absolute sizes of objects are important. Size can also be used in judging the significance of objects and features. It may be the deciding factor when distinguishing between objects alike in shape.
2. **Shape:** The general form (which includes the three-dimensional stereoscopic view) may be the single most reliable evidence for identification. The shape of objects/features can provide diagnostic clues that aid identification. Man-made features have straight edges which is not the case with natural features. Roads can have right angle turns, railroads do not. Of all the 8 parameters, shape is frequently the factor that provides the key evidence for the interpreter. This is especially the case with respect to landform interpretation where the external form of a feature is its identifying mark.
3. **Tone:** Tone can be defined as each distinguishable variation from white to black. Variation in tone results from differences in the reflective qualities of objects, e.g., light, dark, etc. It is the brightness of a black-and-white image or the color in a color image. This property of a photograph is a result of the different light reflectivity of the surfaces that compose the earth's crust. No feature has a constant tone, for this will vary with the reflectivity of the object, the weather, the angle of light on an object and moisture content of the surface. The sensitivity of the response of tone to all the aforementioned variables makes it a very discriminating factor. Slight changes in the natural landscape are more easily comprehended because of tonal variations.
4. **Texture:** When changes in tone are too small to be discernable, texture may assist identification, e.g., stippled, granular, rough, smooth, etc. This is a difficult property to describe, but it is essentially a way of characterizing the smoothness or coarseness of the image on the photo. Texture is the distinctive variation of tone across a single object, the frequency of change and arrangement of tones. This is a micro image characteristic. The visual impression of smoothness or roughness of an area can often be a valuable clue in image interpretation. For eg. water bodies are typically fine textured, while grass is medium, and bushes is rough, although there are always exceptions. Texture involves the total sum of tone, shape pattern and size, which together give the interpreter an intuitive feeling for the landscape being analyzed..
5. **Shadow:** It provides a ground view of the object, hence an important clue. Lengths of shadows can be used to determine heights of objects if the surrounding terrain can be assumed to be flat; Photographs shot at low sun angle show shadow patterns which can help identify objects. Steeples and smoke stacks can cast shadows that can facilitate interpretations. Tree identification can be aided by an examination of the shadows thrown. But sometimes shadows can also inhibit interpretation by causing unnecessary hindrances.
6. **Pattern:** The arrangement on the landscape of physical and cultural features is often distinctive and may be useful for recognition and evaluation. Pattern

is the spatial arrangement of objects. Pattern can be either man-made or natural. Pattern is a macro image characteristic. It is the regular arrangement of objects that can be diagnostic of features on the landscape. Pattern can also be very important in geologic or geomorphologic analysis. The pattern of man-made or natural objects is frequently a vital clue to their identity.

7. **Site:** The location on the landscape can contribute to identification, e.g., particular vegetation may appear in specific locations only. How objects are arranged with respect to one another; or with respect to various terrain features, can be an aid in interpretation. Aspect, topography, geology, soil, vegetation and cultural features on the landscape are distinctive factors that the interpreter should use when examining a site. The relative importance of each of these factors will vary with local conditions, but all are important. Just as some vegetation grows in swamps others grow on sandy ridges. Man made features may also be found on rivers or on a hill top.

8. **Associated features:** Features commonly found adjacent to the object under investigation are called associated features. These have a characteristic appearance and so immeasurably assist photo interpretation, e.g., rocks and soil, water, vegetation (woods, grasslands, crops), roads, railways, towns and historic sites. Some objects are so commonly associated with one another that identification of one tends to indicate or confirm the existence of another. Association is one of the most helpful clues in identifying man made installations.

In some cases, a single such element is alone sufficient for successful identification; in others, the use of several different elements will be required.

Scale in aerial photographs

Scale is the relationship between distance on a map and distance on the ground. The same idea applies to air photos. Most photos have an approximate scale that can be used to measure objects on the photo. Scales of air photos used for mapping and GIS typically range from about 1:6,000 to 1:80,000. A scale of 1:6,000 would be much more detailed and larger for a given area. A 1:80,000 photo would reduce an area to a much smaller representation.

The scale of a photo depends on two factors: the camera lens (Focal length of lens) and the height of the camera above the ground. For a given camera, the scale can only be adjusted by flying higher or lower. The scale can be made larger (more detailed) by flying lower, or smaller (less detailed) by flying higher.

There are four basic methods of determining the scale of an aerial photograph which, in decreasing order of accuracy, are as follows:

i. The relationship between two points on the ground of known distance, and the same two points on the photo. (Note that the scale may vary for other locations on the same photograph if there is significant relief variation);

ii. The relationship between two points on the map and the same two points on the photo;

iii. The relationship between an object on the ground, whose dimensions are known and the same object on the photograph;

iv. The relationship between the focal length of the camera lens and the altitude of the camera lens,

e.g., focal length (f) = 15 cms, altitude (H) = 1,500 m;

Scale= 15/ 1500 * 100 = 1: 10,000

One problem with scale of photos is that the scale usually is not consistent throughout the photo. This is because of differences in elevation (relief) in the landscape of the photo. Objects standing higher or lower in the landscape are displaced from their true "map" position.

Stereoscopic Views

Another useful tool in interpreting aerial photographs is the ability to view photos stereoscopically. Stereo viewing is very similar to the way you perceive things in terms of depth or the distance to objects. For nearby objects, you can tell if something is close or farther away. You can do this because you have stereo (binocular) vision. If you use only one eye, you may have trouble judging the distance to objects, especially if you aren't sure of their size. Two eyes allows you to have depth perception. A stereoscope is a convenient way to view stereo pairs. It's difficult to train your eyes to look at a stereo pair in the proper way to see the overlap and 3-D effect. A stereoscope uses lenses and/or mirrors to place the photos so that you see the 3-D perspective more easily. We will have some examples of stereo pairs under stereoscopes in class for you to examine and see this effect.

12.3 REQUIREMENTS

- Aerial photograph
- Stereoscope
- Hand lens

12.4 PROCEDURE

1. Using the hand lens and stereoscope and in view of the above given principles and the 8 parameters, identify the features of the aerial photograph.
2. Try to calculate the scale if the details of the camera lens etc. are given.
3. Note down all the features and try to interpret the photograph by giving a brief summary of your observation.

12.5 OBSERVATION

Note and describe all the parameters:

1. Size
2. Shape
3. Tone
4. Texture
5. Shadow
6. Pattern
7. Site
8. Associated features

12.6 RESULT

The following interpretations are drawn from the aerial photograph:

1. Size
2. Shape
3. Tone
4. Texture
5. Shadow
6. Pattern
7. Site
8. Associated features

12.7 PRECAUTIONS

1. Examine the photograph carefully.
2. To avoid discrepancy, examine photographs atleast twice.

III EXERCISES BASED ON ROCKS AND SOIL ANALYSIS

EXPERIMENT 13

IDENTIFICATION OF IGNEOUS, SEDIMENTARY AND METAMORPHIC ROCKS

A rock is defined as a natural occurring solid cohesive aggregate of one or more mineral or mineral materials. Rocks are made of minerals, like quartz, calcite, feldspars, and micas. Most rocks are made from more than one mineral, but there are quite a few kinds that are made from only one mineral. Minerals are not rocks, rocks are made of minerals. Based on their process of formation Rocks can be broadly classified into three groups.

1. Igneous rocks
2. Sedimentary rocks
3. Metamorphic rocks

Sedimentary rocks makes up to 66% of the earth's crust, with 34 % being the igneous and the metamorphic and igneous rocks forming the majority of this 34 %. The reason why sedimentary rocks accounts for most of the rocks on the earth's surface is because they are mainly found ocean floor basins which accounts to 70% of total area of the earth.

Igneous rocks: The word igneous is derived from the Latin word ignis meaning fire. Igneous rocks are formed as a result of solidification or crystallization and cooling of magma. As they are formed from magma they are also called magmatic rocks. They are associated with volcanic activity and their distribution is controlled by plate tectonics. Igneous rocks are divided into two main categories: Plutonic (intrusive) rock and volcanic (extrusive). Plutonic or intrusive rocks result when magma cools and crystallizes slowly within the Earth's crust. A common example of this type is granite. Volcanic or extrusive rocks result from magma reaching the surface either as lava or fragmental ejecta, forming rocks such as pumice or basalt. Some common examples of igneous rocks are: Granite, Pumice, Basalt, Diabase, Diorite, Gabbro, Obsidian, Rhyolite, Scoria

Sedimentary rocks: They forms the major part of earth crust. They are formed from particles, called sediment, that are worn off other rocks. The particles are sand, silt, and clay. They are formed by the deposition of material at the Earth's surface and (or) within bodies of water. Sedimentation is the collective name for processes that cause mineral and/or organic particles (detritus) to settle and accumulate or minerals to precipitate from a solution. Sediments can be detrital, chemical or organic sediments. Detrital sediments are mechanically eroded from pre-existing rocks. Sedimentary rocks are important in regard to resources like limestone deposits, coal and oil. Some common sedimentary rocks are sandstone, limestone, shale, conglomerate, and gypsum.

Metamorphic rocks: Metamorphism means change – changes that a rock undergoes when it is moved from the place of its origin to a new environment characterized by marked changes in the physical (pressure and temperature) and physico-chemical (partial pressure of O2) conditions. The change in ambience results in structural and mineralogical reconstitution of the rock in order to achieve equilibrium with the imposed new conditions. Metamorphic rocks are basically

rocks that have experience change due to high pressure and temperature or both. The pressure can come from being buried very deep in the earth's crust, or from the huge plates of the earth's crust pushing against each other. Metamorphic rocks are divided in to two main groups, foliated (mineral banded) and not-foliated (no mineral bands). Foliated rocks are easy to identify. Examples of Metamorphic Rocks are Gneiss, Marble, Quartzite, Schist, Serpentinite, Slate etc.

The three rock types are further classified based on chemistry and formation.

Rocks, like mountains, do not last forever. The weather, running water, and ice wear them down. All kinds of rocks become sediment. Sediment is sand, silt, or clay. As the sediment is buried it is compressed and material dissolved in water cements it together to make it into sedimentary rock. If a great amount of pressure is exerted on the sedimentary rock, or it is heated, it may turn into a metamorphic rock. If rocks are buried deep enough, they melt. When the rock material is molten, it is called a magma. If the magma moves upward toward the surface it cools and crystallizes to form igneous rocks. This whole process is called the **Rock Cycle**.

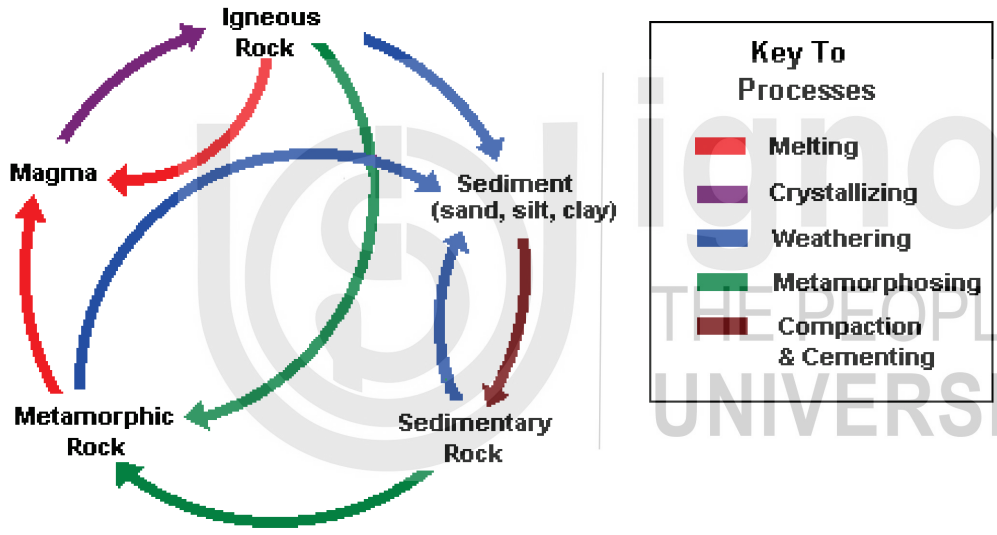


Figure 13.1: THE ROCK CYCLE

13.1 OBJECTIVES

After studying and performing this exercise you must be able to:

- Know about rocks and their different types
- Explain the origin, formation, composition and texture of rocks
- Explain the rock cycle
- Know how to use the rock key
- Know the identification of different types of rocks

13.2 PRINCIPLE

In order to identify or classify a rock, three things must be considered: 1. origin, 2. composition, and 3. texture. Rocks are composed of minerals. The common minerals found in rocks are: quartz, feldspar, mica, calcite, hornblende, etc.

Rock Identification key: The Rock Identification key is a dichotomous key with each question having two options. It is one of the easiest and quick method to identify and named rocks. In order to use **The Rock Identification Key** there are a few things you need to know:

Crystals: Crystals are what minerals form when they are free to grow in nature. In rocks, crystals grow up against each other. They can not grow as the quartz crystal does in open space. Crystals in rocks have straight edges and they very often show flat shiny faces that reflect light like tiny mirrors.

Grains: Grains that are not crystals in rock do not have flat shiny faces. They are rounded, like grain of sand, or jagged, like a piece of broken rock.

Grain Size: Grain size in rocks can mean the size of crystal grains or of fragments:

- **Coarse Grained:** Most of the rock is made of grains as large as rice, or larger.
- **Medium Grained:** The individual grains can be seen without a magnifier, but most of the rock is made of grains smaller than rice.
- **Fine Grained:** The individual grains cannot be seen without a magnifier (or microscope).

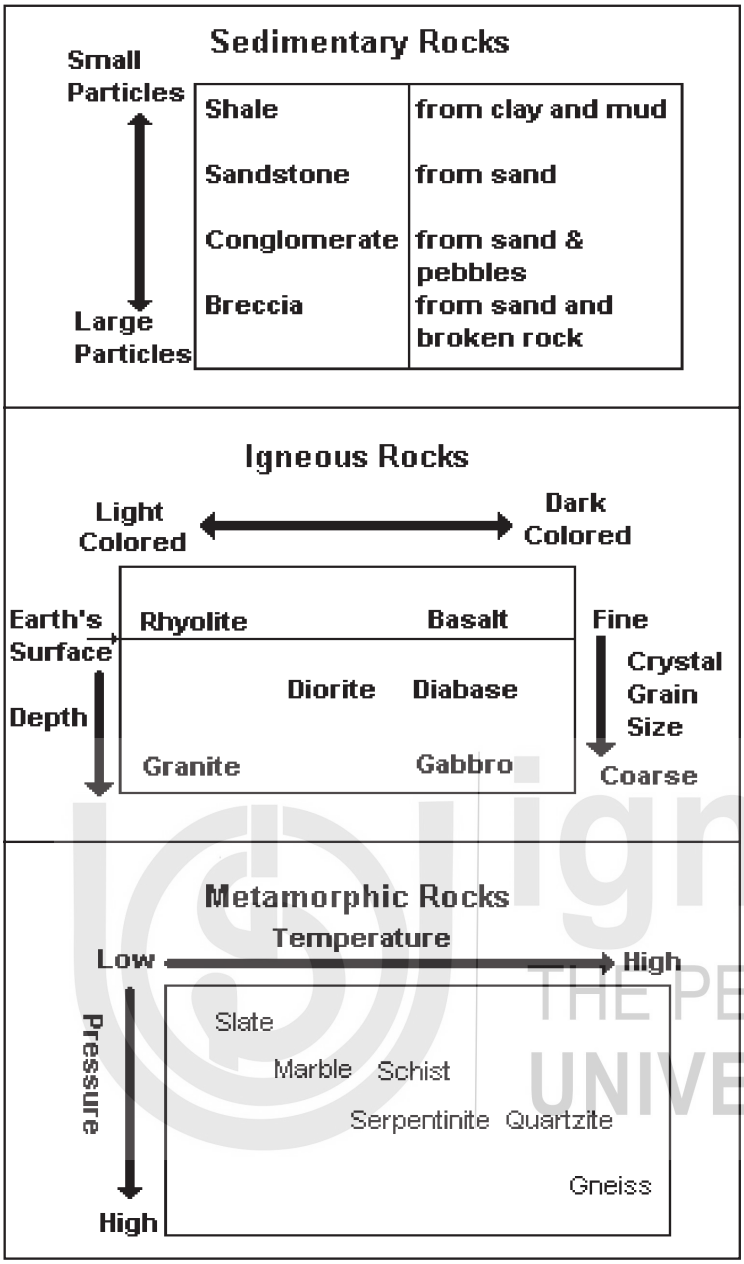
Layers: Layers in rocks show in different ways.

- In some rocks different colored minerals are lined up in ribbons. Usually there are two colors, often black and white, or green and white, of black and tan or pink. Ribbon like layers are found in the *rock, gneiss*.
- In schists, the layers are most often thin layers of mica or chlorite around lens shaped masses of feldspar or quartz. The top and bottom is almost always mica or chlorite.
- In sandstones, different sized sand grains sometimes show as different colors. When the grains are sorted by running water or wind, they show different shades of the same color.
- The layers in slate are very thin and straight. The top and bottom layers are usually flat and quite smooth.

Ribbon like Layers	Mica like Layers	Particle Layers	Thin Cleavage Layers
			
in Gneiss	in Schist	in Sandstone	in Slate

Gas Bubbles: Gas bubbles in rock are sort of round or elongated holes. In pumice, the bubbles may be very tiny to the size of a match head. They are a glass froth that may look something like a sponge or gray, glassy soap bubbles. In scoria or vesicular basalt, the bubbles are larger, often as large as peas. They look like small pockets in the rock.

Few characteristics of the three types of rocks:



13.3 REQUIREMENTS

Unknown rock material

Rock Identification Key by Don Peck

Oil paint and brush

Notebook

Stationery

13.4 PROCEDURE

1. Collect clean fresh specimens from field.
2. Make a label that has the name of the rock and the location where it was collected.
3. Assign a number to each rock.

4. Record in a notebook the name, location where you found it, and number of the rock.

5. Paint a small white rectangle on each rock, and write the rock's number on it.

6. With the help of the Rock Identification Key by Don Peck

7. **Using The Rock Key:**

   a. As you use **The Rock Key**, you will find a lot of questions .

   b. Each question has two choices “yes or no”.

   c. Depending upon whether the answer is yes or no you are directed to next question under the “Go to __” option .

   d. If it is the last question to finding the name of the rock, you will be directed to go to the name and description of the rock.

8. Identify the rock sample given to you by observing the various properties of the rock and using the rock key

13.5 OBSERVATIONS AND CALCULATIONS

Note down all the properties of the rock by analyzing all the yes answers in the rock identification key.

13.6 RESULT

The given rock sample was identified as _____

13.7 PRECAUTIONS

1. Always wear safety glasses or goggles when breaking rocks.

2. Use only hammers that are intended for breaking rocks.

3. Always work under the guidance of your mentor.

The Rock Identification Key - by Don Peck
1. Is the rock made of crystal grains? (Does it have a lot of flat, shiny faces - maybe tiny to small - that reflect light like little mirrors? You may need to use a magnifier.) YES The rock is made of crystal grains with flat shiny surfaces. . . **Go to 2** NO There are no (or not many) shiny, flat, crystal grains. . . **Go to 3**
2. Does the rock have both layers and crystal grains? (Look carefully for layers , especially along the edges of the rock. You may need a magnifier.) YES The rock has both layers and crystals. . . **Go to 4** NO The rock has crystals, but it has no layers. . . **Go to 5**
3. Does the rock have layers but not crystal grains? (Look carefully for layers, especially along the edges of the rock. You may need a magnifier.) YES The rock has layers, and crystal grains are not visible. . . **Go to 11** NO The rock has no layers, and crystal grains are not visible. . . **Go to 12**

4. Do the layers look like ribbons or bands of minerals running through the rock; and is the rock kind of blocky? (The bands of minerals may be straight or wavy. The rock breaks into blocky chunks, not along its layers.)

YES The rock has crystals, layers that look like ribbons or bands of minerals running through it, and is kind of blocky . It is. . . **Go to 23**

NO The rock has crystals and layers that are thin and do not look like ribbons of minerals. It breaks along the layers. It is. . . **Go to 24**

5. Is the entire rock mostly light colored, compared to other rocks? (Look at the whole rock, not just mineral grains in the rock.)

YES The rock is mostly light colored or light gray minerals grains. . . **Go to 6**

NO The rock is mostly medium gray to very dark colored minerals... **Go to 7**

6. Can you scratch glass with the rock? (If it does, the rock is hard. If it doesn't, the rock is soft.) (Safety note: keep the glass flat on your desk, not in your hand. Carefully press a point of the rock against the glass and pull it about 2cm. Look to see if it scratched the glass. Do not hit the glass with the rock.)

YES The rock scratches glass. It has crystals, but has no layers. . . **Go to 9**

NO The rock does not scratch glass. It has crystals, but has no layers. It is. . . **Go to 25**

7. Is the rock mostly light or medium gray, not very dark gray or black?

YES The rock is mostly light to medium gray, has crystal grains, and is not layered. It is. . . **Go to 31**

NO The rock is mostly very dark gray or black. . . **Go to 8**

8. Can you see crystal grains in most or all of the rock without using a magnifier?

YES The rock is coarse or medium grained, has crystals, and no layers. . . **Go to 10**

NO The rock is fine grained, has crystals, and no layers. It is. . . **Go to 32**

9. Can you see crystal grains in most or all of the rock without using a magnifier?

YES The rock is mostly crystal grains. It is medium or coarse grained, has no layers, and is light colored. It is. . . **Go to 30**

NO The rock is mostly fine grained, it has crystal grains, has no layers, and is light colored. It is. . . **Go to 29**

10. Is the rock coarse grained? (If the rock is coarse grained, most of the rock mostly is made of crystals that are as large, or larger, than rice. If you can see the crystals without a magnifier, but they are smaller than rice, the rock is medium grained.)

YES The rock is made of coarse crystal grains. It has no layers, and is dark colored. It is. . . **Go to 34**

NO The rock is made of medium crystal grains. It has no layers, and is dark colored. It is. . . **Go to 33**

11. Using the point of a steel nail, can you scrape grains of sand off the rock? (Hold the rock over a clean sheet of paper and scrape it hard with the point of the nail. Rub your finger over the paper. Can you feel grains of sand?)

YES The rock has layers. It is made of grains of sand. The rock is. . . **Go to 38**

NO The rock has layers and is not made of grains of sand. . . **Go to 13**

12. Does the rock have gas bubbles in it? (It may look something like a sponge. Look for rounded holes, or glassy bubbles in the rock. They may be tiny {like a pinhead}, small, or large {like a pea})

YES The rock has gas bubbles. . .**Go to 15**

NO The rock has no gas bubbles. . .**Go to 17**

13. Does the rock look like it is composed of mostly only one mineral and has many thin flat layers? (The layers are less than 2mm thick, mostly thinner. not thick layers)

YES The rock has many thin flat layers, seems to have only one mineral, and usually no visible crystals. The rock is. . . **Go to 27**

NO The rock is mostly one mineral, but the layers are thicker (usually more than 4mm). . .**Go to 14**

14. Is the rock definitely green in color, and does it feel slippery?

YES The rock is mostly green and slippery. The rock is. . . **Go to 28**

NO The rock is not green and slippery. The rock is. . . **Go to 39**

15. Is the rock light in weight and mostly light colored (probably gray)?

YES The rock is full of gas bubbles, is light in weight, and is light colored. The rock is. . . **Go to 35**

NO The rock is heavy, dark colored, and has some gas bubbles, but the bubbles are mostly larger. . . **Go to 16**

16. Is the rock dark colored, glassy, with gas bubbles in it? (Does it have some jagged or sharp points?)

YES The rock is dark colored, glassy, with gas bubbles in it. The rock is. . . **Go to 36**

NO The rock is gray or black, has a few gas pockets in it, and has no layers. It is not glassy. The rock is. . . **Go to 32**

17. Does the rock look like black glass with no bubbles in it? (It may have some white "snowflakes" in it ,or some reddish bands in it)

YES The rock looks like black glass. The rock is . . **Go to 37**

NO The rock does not look like a black glass. . . **Go to 18**

18. Using the point of a steel nail, sand can be scraped off the rock. (Use the point of a steel nail to scrape the rock over a sheet of clean paper. Can you feel sand on the paper?)

YES Sand can be scraped off the rock. . . **Go to 19**

NO Sand cannot be scraped off the rock. . . **Go to 20**

19. Does the rock contain sand and larger pieces of rock or pebbles?

YES The rock is composed of sand and pebbles or other larger pieces of rock. . . **Go to 22**

NO The rock is made of sand, but not pebbles or other larger pieces of rock. The rock is. . . **Go to 38**

20. Can the rock scratch glass? (Safety note: keep the glass flat on your desk, not in your hand. Carefully press a point of the rock against the glass and pull it about 2cm. Look to see if it scratched the glass)

YES The rock scratches glass, but it is not made of sand. . . **Go to 21**

NO The rock does not scratch glass. It is not composed of visible crystals. It is. . . **Go to 40**

21. Is the rock white, yellowish, tan, or reddish?

YES The rock is.. . . **Go to 26**

NO The rock is either black or gray. The rock is. . . **Go to 32**

22. Are the larger pieces of rock (that are mixed with the sand) rounded pebbles, not blocky or jagged?

YES The larger pieces are rounded pebbles. The rock is. . . **Go to 41**

NO The larger pieces are jagged and blocky. The rock is. . . **Go to 42**

23.

GNEISS
What Type of Rock Is It?: Metamorphic What Does It Look Like?: Gneiss is usually light in color, but it can be quite dark. It looks like it has ribbons or stripes of minerals running through the rock. The grain size is usually fairly coarse. Gneiss usually breaks into blocky pieces, not along the layers. Unlike granite, in which the crystals are randomly arranged, the crystals in gneiss are lined up and in layers. Gneiss is a tough and hard rock. **What Minerals Make Up the Rock?:** Almost always: feldspars, quartz, and mica. Sometimes: kyanite, garnet, hornblende, tourmaline, magnetite, and many others. **How Was It Formed?:** Gneiss is formed from another metamorphic rock, called schist. The schist formed from fine grained sedimentary rock (often a shale). Gneiss can be formed also from some igneous rocks, especially granite. It is usually formed under great pressure from moving plates of the earth's crust. **Compare To:** schist granite

24.

SCHIST
What Type of Rock Is It? Metamorphic **What Does It Look Like?** Top and bottom layers are usually a silvery, to green, to brown, to black mica, or a green to very dark green chlorite. The micas are often in small flaky crystals. Layers are usually thin, often with lens like layers of quartz between the mica layers. Layers may be somewhat wavy. Grain size varies from medium to coarse. Schist usually splits easily along the layers of mica, unlike gneiss. **What Minerals Make Up the Rock?** quartz, feldspar, mica (muscovite, biotite). Sometimes: chlorite, garnet, hornblende, actinolite, kyanite, magnetite, pyrite, staurolite, tourmaline, and many others. **How Was It Formed?** Schists are usually formed from shales that were formed from clay or sandy clay, sometimes with a little lime, sometimes from rocks and sediments from volcanoes. Schists are most often formed when plates of the ocean floor push under, into, or up onto a continent. It is the sea floor rocks that get crunched to form schists. **Compare To:** gneiss, shale, slate, serpentinite

25.

MARBLE
What Type of Rock Is It? Metamorphic **What Does It Look Like?** Often pure white. It may be streaked or patchy gray, green, tan, or red. Marble is fine grained to very coarse grained and crystals are usually easy to see. The rock is soft; it will not scratch glass (quartzite may look like a fine grained marble, but easily scratches glass). The powdered marble will often fizz with white vinegar. If it does not fizz, it may be dolomitic marble. **What Minerals Make Up the Rock?** calcite, or dolomite (dolomitic marble); Sometimes: graphite, pyrite, mica, tremolite, and a few others **How Was It Formed?** Marble forms from the metamorphism of limestones. **Compare To:** quartzite , limestone

26.

QUARTZITE
What Type of Rock Is It? Metamorphic **What Minerals Make Up the Rock?** quartz; Sometimes, a little: mica, feldspar, magnetite, pyrite, ilmenite, garnet, and any of a few others. **What Does It Look Like?** If the quartzite is pure quartz it is white. It may have a yellowish to reddish color if it contains iron minerals. Rarely, it is black if it contains a lot of magnetite. Sometimes, using a magnifier, the grains of sand from which it formed can be seen. The rock breaks through the grains, not around them (sandstone breaks around the grains). Quartzite often shows lighter colored flakes on a broken surface, where air is behind a very thin chip. Unlike marble, quartzite is very hard and easily scratches glass. **How Was It Formed?** Most quartzite is metamorphosed sandstone. **Compare To:** marble, sandstone

27.

SLATE
What Type of Rock Is It? Metamorphic **What Minerals Make Up the Rock?** micas, feldspars, quartz (but they can not be recognized because the grains are so small you would need a microscope to see them); Sometimes contain: pyrite **What Does It Look Like?** Slate can be black, gray, brownish red, bluish gray, or greenish gray. It is very fine grained and has thin, quite smooth, flat layers. Unlike shale, slate easily splits into thin flat pieces. It often will scratch glass, with a little difficulty. **How Was It Formed?** Slate is usually formed from clay sediments or shale that has been heated and put under pressure by plate collisions. The pressures and temperatures that form slate are lower than those that form schist. **Compare To:** shale, schist, serpentinite

28.

SERPENTINITE
What Type of Rock Is It? Metamorphic **What Does It Look Like?** Serpentinite feels very slippery. It is more a broken rock than it is a layered rock. The "layers" are sort of flat plates of green rock. They may be thin or more than 2cm thick. Serpentinite is usually green to grayish-green. The flat plates may have long scratch like grooves in them. It may be dull or nearly glassy looking. When serpentine is dull it may be fine to coarse grained. When it is glassy it looks very smooth and has no visible grains. **What Minerals Make Up the Rock?** Mostly antigorite, amesite, and lizardite. Sometimes: chrysotile (a type of asbestos), brucite, magnesite, chromite, magnetite and garnets. Talc is often found because serpentine alters to talc. **How Was It Formed?** When an ocean floor plate collides with a continental plate, giant slices of the oceanic crust are pushed up into the rocks of the continent. A rock, called peridotite, at the bottom of the oceanic plate is changed to serpentinite because there is less weight on it, the temperature is lower, and water circulates through it. Serpentinite is usually found in mountains that were once at the edge of a continent. Another way serpentinite can form is from peridotites that crystallize deep in the earth's crust from magma. The peridotites are gradually uncovered by erosion, and as they get close to the surface, they alter to serpentinite. **Compare To:** diabase, gabbro, slate, schist

29.

RHYOLITE
What Type of Rock Is It? Igneous **What Minerals Make Up the Rock?** quartz, feldspars; Sometimes contain: biotite, diopside, hornblende, zircon **What Does It Look Like?** Usually light colored; light gray, tan, reddish, greenish, brown. Fine grained, but often contains scattered larger crystals. May contain small pockets that were gas bubbles. Sometimes shows flow lines or bands. **How Was It Formed?** Rhyolite is a volcanic rock. It forms from the rapid cooling of a magma or lava that contains a lot of silica (quartz). The molten material often contains gas bubbles which freeze into the rock. Pumice is a kind of rhyolite that has really a lot of tiny gas bubbles in it. **Compare To:** pumice, basalt

30.

GRANITE
What Type of Rock Is It? Igneous **What Minerals Make Up the Rock?** quartz, feldspars (microcline, orthoclase, albite), biotite, muscovite; Sometimes contain: hornblende, augite, magnetite, zircon **What Does It Look Like?** The feldspars give granite most of its color, which may be white to light gray, yellowish, or pink. The quartz is usually smoky gray or white. Black specks of biotite, or sometimes hornblende, are common. So is silvery to brownish muscovite. Granite is coarse grained to very coarse grained. The crystals are randomly arranged (unlike gneiss where they are in lines or layers). **How Was It Formed?** Granite forms deep in the earth's crust from cooling magma. The magma contains a lot of silica (quartz). Slow cooling produces the large crystals in granite. **Compare To:** gneiss diorite

31.

DIORITE
What Type of Rock Is It? Igneous **What Minerals Make Up the Rock?** Dark colored plagioclase, hornblende, pyroxene, and sometimes a little quartz. May contain: light colored plagioclase feldspars, but only a little. **What Does It Look Like?** Mostly it looks like a dark colored granite. The dark colored plagioclase feldspars and pyroxenes give it a darker color. It is usually medium to dark gray. Unlike granite, diorite has no mica, or very little, and those are dark colored. It is coarse grained (larger than rice). **How Was It Formed?** Diorite forms deep in the earth's crust from cooling magma - just like granite. But, the magma does not contain a lot of quartz or the light colored minerals that make up the granite. Instead it contains only dark colored minerals. **Compare To:** granite, diabase

32.

BASALT
What Type of Rock Is It? Igneous
What Does It Look Like? Basalt is dark gray to black. When exposed to the weather, it may turn yellow or brown on its surface. Basalt is fine grained rock You may or may not be able to see crystals with a hand magnifier. The crystals are often microscopic. Basalt is a hard, tough rock. It is difficult to break. Sometimes, basalt contains gas bubbles. It is then called vesicular basalt.
What Minerals Make Up the Rock? plagioclase feldspars, augite, hypersthene, olivine
How Was It Formed? Basalt is a volcanic rock. It is formed from a magma that is rich in iron and magnesium, and poor in silica (quartz). The magma erupts from a volcano or a fissure (a crack in the earth's surface) as lava. Because the lava cools rather quickly, basalt is fine grained. there is not time enough for the grains to become larger.
Compare To: rhyolite, diabase, gabbro

33.

DIABASE
What Type of Rock Is It? Igneous
What Does It Look Like? Diabase is dark green to black, sometimes with some white crystals scattered through it. When exposed to the weather its surface often turns brown. It has a medium grain size (you can see them without a magnifier, but they are smaller than rice). It is a tough, hard rock.
What Minerals Make Up the Rock? plagioclase feldspars, augite; Sometimes contains: hornblende, magnetite, olivine, glass
How Was It Formed? Diabase forms from a magma that is rich in iron and magnesium, and poor in silica (quartz). The magma is forced into cracks or between layers of rock near the earth's surface. Diabase is from the same kind of magma as basalt, but because it cools more slowly, it develops slightly larger crystals.
Compare To: basalt, gabbro, diorite, serpentinite

34.

GABBRO
What Type of Rock Is It? Igneous
What Does It Look Like? Gabbro is dark green to black. When exposed to the weather its surface often turns brown. It has a large grain size (most of the rock is grains larger than rice).
What Minerals Make Up the Rock? plagioclase feldspars, augite, hypersthene, olivine; Sometimes contains: magnetite, chromite, titanite, ilmenite.
How Was It Formed? Gabbro forms from a magma that is rich in iron and magnesium, and poor in silica (quartz). The magma cools and crystallizes deep below the earth's surface. Gabbro is from the same kind of magma as basalt and diabase, but because it cools more slowly, it develops larger crystals.
Compare To: basalt, diabase, serpentinite

35.

PUMICE
What Type of Rock Is It? Igneous **What Does It Look Like?** Pumice is very light gray to a medium gray in color. It contains a large number of gas bubbles, each surrounded by a thin layer of volcanic glass. Pumice looks something like a sponge. It is very light in weight. Most pieces of pumice will float on water. Flow lines or bands may show. **What Minerals Make Up the Rock?** glass, any mineral grains are unusual. **How Was It Formed?** Pumice is explosively blown out of volcanoes. It comes from a highly silicic magma that is thick and sticky. The gases that are trapped in the bubbles are the same that cause the explosive eruption. It is the same kind of magma which would form rhyolite or granite. **Compare To:** scoria, rhyolite

36.

SCORIA
What Type of Rock Is It? Igneous **What Does It Look Like?** The color is usually black, dark gray, brown, or dark green. Scoria is glassy, smooth to rough, and contains gas bubbles. Unlike pumice, it has many fewer, usually larger bubbles, and is moderately heavy. **What Minerals Make Up the Rock?** mainly a glass **How Was It Formed?** Scoria usually is from the top of a lava flow, so it is volcanic. It forms from a somewhat sticky lava. Because it is on the top of the flow, it cools rather quickly, before many crystals start to form. **Compare To:** pumice, basalt

37.

OBSIDIAN
What Type of Rock Is It? Igneous **What Does It Look Like?** Obsidian is a glass and is usually black, although sometimes it may be slightly grayish or greenish. It may include some white crystals that look like snowflakes (snowflake obsidian). It may include swirls of a red color. Obsidian breaks and chips like glass. The location where the chip came out is scoop shaped, like the inside of a clam shell. The chip often has ridges that that are semicircular. This kind of break is called a conchoidal fracture. **What Minerals Make Up the Rock?** black glass **How Was It Formed?** Obsidian is volcanic. It forms from rapid cooling lava that has a lot of silica. The lava cools so fast that crystals do not have time to form.

38.

SANDSTONE
What Type of Rock Is It? Sedimentary **What Does It Look Like?** Sandstone is often red to brown, light gray to nearly white. Sometimes it is yellow or green. It usually is composed of rounded grains that are all of the same size; and it is usually medium grained. Some sandstones show slight color variations in layering. **What Minerals Make Up the Rock?** quartz; Sometimes contains: feldspars, mica, glauconite (in green colored sandstone), magnetite, garnet, rutile, ilmenite **How Was It Formed?** quartz sand that is produced by the weathering of other rocks (such as granite, gneiss, and other sandstones) is deposited by rivers, waves, or wind. The sediment may have been a sand bar, an ocean beach, or desert sand dunes. The sand is buried under other sediments, compacted by the weight of those sediments, and cemented by material dissolved in water that seeps through it. **Related Rocks: Arkose:** Usually red or pink, may be gray. Grains are angular. Arkose contains more than 25% feldspar with quartz. Medium to coarse grained. Greywacke: Black or dark green. Usually contains coarse angular grains included with fine grains.

39.

SHALE
What Type of Rock Is It? Sedimentary **What Does It Look Like?** Shale may be black, gray, red, brown, dark green, or blue. It is fine grained, so particles usually can not be seen. When moistened, shale usually smells like wet mud. What Minerals Make Up the Rock? clay minerals; Sometimes with some quartz sand, pyrite, gypsum **How Was It Formed?** Clay sediments settle in quiet lakes, lagoons, bays, or off-shore areas. When buried and compacted the clays become shale. Iron oxides often help to cement the particles together. **Compare To:** slate schist

40.

LIMESTONE
What Type of Rock Is It? Sedimentary **What Does It Look Like?** Limestone is usually white, gray, tan, or yellow. It may contain impurities to make it red or black. Fossils are often found in limestone. It may be very smooth or even sugary, fine grained, or medium grained. The powdered rock will usually fizz in white vinegar. Unlike marble, limestone is not composed of visible crystals. **What Minerals Make Up the Rock?** mostly calcite **How Was It Formed?** Most limestone is formed by a chemical reaction in sea water. The reaction makes a lime mud which sinks to the bottom to for the limestone. Some limestones are formed from buried coral reefs. **Related Rocks:** Dolostone (doe'-low-stone) looks like limestone, but is composed of the mineral, dolomite. Powdered dolostone does not fizz with white vinegar. Dolostone forms on the ocean floor. **Compare To:** marble

41.

CONGLOMERATE
What Type of Rock Is It? Sedimentary **What Does It Look Like?** Conglomerate looks like a mixture of sand and different sizes of rounded pebbles. The pebbles are the important observation. **What Minerals Make Up the Rock?** mostly quartz **How Was It Formed?** Sand and pebbles collect along sea shores, lake shores, or river banks. They are compacted by the weight of sediments that collect above them and cemented by material dissolved in the water that seeps through them. **Related Rocks:** Breccia (brech'-ee-uh) looks like conglomerate, but the "pebbles" in it are jagged and blocky, not rounded.

42.

BRECCIA
What Type of Rock Is It? Sedimentary **What Does It Look Like?** Like conglomerate, but the "pebbles" in it are jagged and blocky, not rounded. **What Minerals Make Up the Rock?** The "cement" holding the rock together is mostly quartz, but the pebbles can be almost any kind of rock - often quartzite, granite, or another tough rock that does not easily erode into sand or silt. **How Was It Formed?** Where the environment is dry - like in deserts. When mountains erode broken pieces of rock don't get carried away be streams. They just pile up. When they get deep enough, the weight above compresses them and they get cemented together. **Compare To:** Conglomerate

EXPERIMENT 14

Study of soil profile and physical characteristics of soil

Soils are porous natural bodies composed of inorganic and organic matter. They are formed by the interaction of the earth's crust with atmospheric and biological influences. They are dynamic and have properties that reflect the integrated effects of those interactions which happen at the earth's surface.

Soils are landscapes as well as profiles. Soils develop in the form of layers. If we dig a massive hole of about 2 to 6 m vertically downwards into the ground, we will notice various layers of soil horizons. A look at these layers from a distance, gives a cross-sectional view of the ground (beneath the surface) and the kind of soils and rocks that make up the soil profile. This cross-sectional view is called as the Soil Profile. The profile is made up of layers, running parallel to the surface, called Soil Horizons. From construction of buildings to various infrastructure projects, characteristics of soil sections are very important.

Soil physical properties control the mechanical behavior of soils and will strongly influence land use and management. The physical properties of soil also the spatial patterning of vegetative cover, overall community structure and productivity

These physical properties are texture, temperature, bulk density, particle density, and porosity etc.

14.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain the occurrence and distribution of various layers in soil profile and their importance.
- Know about the various physical properties of soil like texture, temperature, bulk density etc.
- Analyze different physical properties

14.2 PRINCIPLE

Soil Profile: A soil profile is a vertical exposure of the soil that reveals the combination and types of horizons. The combination of master horizons, thickness of the horizons, and sequence in which they occur in the profile can cause different chemical, biological, and physical properties in each soil.

Soils consist of one or more distinct layers called horizons. These layers are referred to as O, A, E, B, C and R depending on their position and nature. Each soil horizon (layer) may be slightly or very much different from the other layer existing above or below it. Each horizon also gives an idea about the makeup, age, texture and other characteristics of that layer. The layers are divided as top soil layer, sub-soil layer and the bed rock layers.

The A,B,C horizons are further subdivided into micro-layers as A1, A2, A3, B1, B2, and B3.

In some profiles, the letter E is not used in the zonation process.

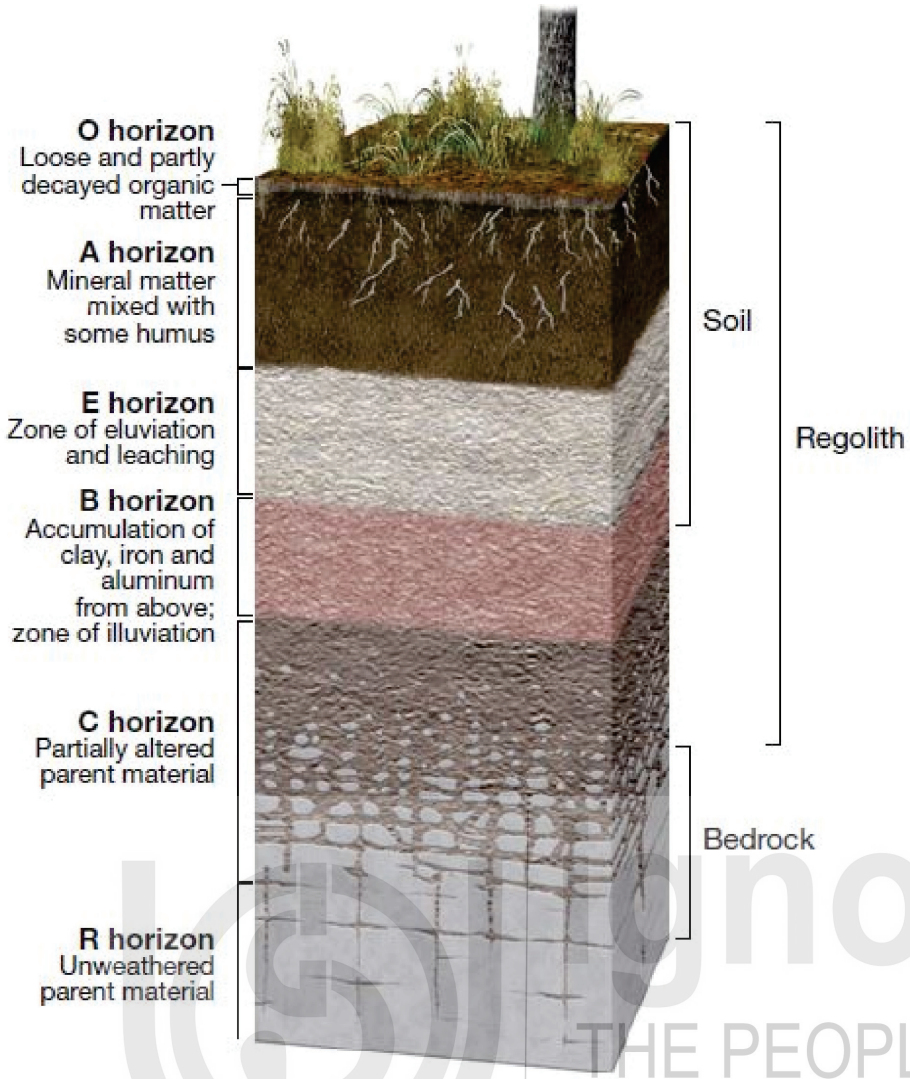


Figure 14.1: The Soil Profile

The O-Horizon (humus + litter layer):

Topmost layer dominated by organic material. The O horizon is very common in many surfaces with lots of vegetative cover. It is the layer made up of organic materials such as dead leaves and surface organisms, twigs and fallen trees. It has about 20% organic matter.

It is possible to see various levels of decomposition occurring here (minimal, moderately, highly and completely decomposed organic matter). This horizon is often black or dark brown in color, because of its organic content. It is the layer in which the roots of small grass are found.

The A-Horizon (Top soil + Root Zone):

The A horizon is usually at the surface or below O horizon, generally called topsoil in agriculture. Typically, the A horizons are made of sand, silt and clay with high amounts of organic matter. This layer is most vulnerable to wind and water erosion. It is also known as the root zone. It has more organic carbon than underlying layers and is the best environment for plants and microbes to grow. Sometimes this layer is missing or reduced due to erosion or topsoil removal. Also, all surfaces resulting from ploughing, pasturing, or similar disturbances are referred to as A horizons.

The E-Horizon:

The E horizon is usually lighter in color, often occurring below the O and A horizons. It is often rich in nutrients that are leached from the top A and O horizons. It has lower clay content. It is common in forested lands or areas with high quality O and A horizons. It is characterized by eluviation (removal of materials such as silicate clay, iron, aluminum, or organic matter), *if distinct from the A horizon. Frequently not present.* It is usually more pale colored than the A horizon.

The B-Horizon (Mineral dominated zone):

The B-horizon has some similarities with the E-horizon. This horizon is formed below the O, A and E horizons and may contain high concentrations of silicate clay, iron, aluminum and carbonates. It is also called the illuviation zone because of the accumulation of minerals. It is the layer in which the roots of big trees exist. It is dominated by loss of most or all of the original rock structure and shows evidence of soil formation such as illuviation (concentration of the silicate clay, iron, aluminum, or humus from higher horizons), development of soil color or structure, or brittleness.

The C-Horizon (saprolite layer):

C horizons are mineral layers which are not bedrock and are little affected by pedogenic (soil-forming processes) processes and lack properties of O, A, E or B horizons. The C horizon lacks all the properties of the layers above it. It is mainly made up of broken bedrock and no organic material. It has cemented sediment and geologic material. There is little activity here although additions and losses of soluble materials may occur. The C horizon is also known as saprolite.

The R-Horizon:

The R horizon is the underlying bedrock horizon. It contains materials that are compacted and cemented by the weight of the overlying horizons. It is the hard layer of unweathered parent material. *All kinds are rock types exist as basement.*

Soil Physical Characteristics

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.

TEXTURE: Soil texture and structure are considered "master variables", meaning that texture and structure directly influence a large number of other soil properties. For example, in comparing a clayey soil and a sandy soil, one would expect the clayey soil to have larger specific surface area, more cation exchange capacity, more total porosity, less macroporosity, and more organic matter than the sandy soil. Thus, by simply knowing the texture of the soil, inferences can be made in regard to many soil properties. Soil texture is an important indicator of the ability of soil to absorb and hold both water and plant nutrients. Since soils are a mixture of different size particles, they are classified using the soil textural triangle.

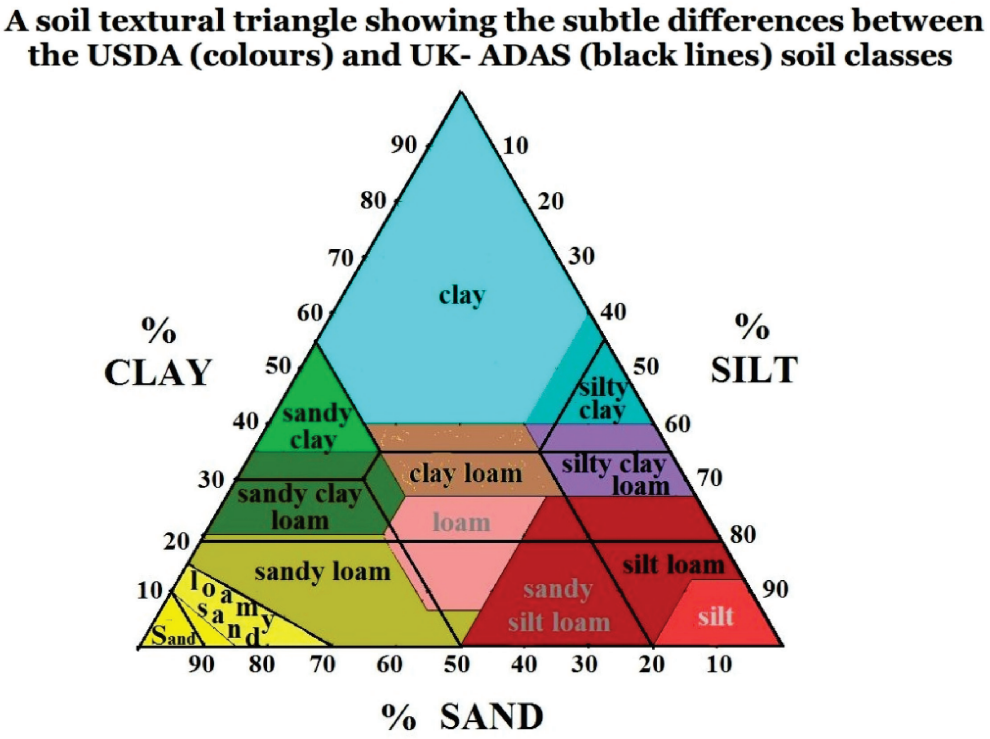


Figure 14.2: The Soil Textural Triangle

The Different Soil Types are:

1. Sands: 85-90% sand and <10% clay and silt
2. Loamy Sands: 70-85% and <15% clay
3. Sandy Loams: > 52% sand and < 20% clay
4. Loam: 7-27% clay, 28-50% silt, and <52% sand
5. Silt Loam: >50% silt, 12-27% sand clay; or 50-80% silt and <12% clay
6. Clay Loam: 27-40% clay and 20-45% sand
7. Clay: 27- 40% clay and less than 45% sand and less than 40% silt

Soil texture influences nearly every aspect of soil use and management. Many of the physical and chemical properties of the soil depend on how fine (clayey) or coarse (sandy) a soil is. Soil texture is a permanent feature unless soils are subjected to rapid erosion, deposition, or removal. Moreover, much of the reactivity of soils is related to the amount of surface area available. As the average particle size decreases, the surface area per unit weight increases

Soil texture can be determined quantitatively either by using the hydrometer method or the mechanical sieving method and can be estimated using the texture by feel method.

TEMPERATURE: Soil temperature is the factor that drives germination of seeds. Soil temperature directly affects plant growth. Most soil organisms function best at an optimum soil temperature. Soil temperature impacts the rate of nitrification.It also influences soil moisture content, aeration and availability of plant nutrients. The best time to measure it is in June, July and August during the growing season to reflect soil health benefits. The most suitable time of day is between 1 and 2 p.m. and the appropriate depth is about 4 inches below the soil surface, under bare soil. Temperature affects the physical, chemical and biological properties of the

soil and ultimately plant growth. Soil thermometers are the most common tool for measuring soil temperatures. There are special soil temperature gauges used by some farmers and soil sample companies, but a standard digital thermometer will work for general soil health assessment.

BULK DENSITY, PARTICLE DENSITY AND POROSITY: Soil represents a unique arrangement of solids and voids. The voids, or pore space, are important for air and water movement and storage. The total pore space consists of the voids between sand, silt, and clay particles and voids between soil aggregates. Therefore, texture and structure govern the amount of soil pore space. Organic matter affects the solids portion of the soil but also influences porosity indirectly through its effect on structure.

Density refers to a mass per unit volume.

Bulk density of a soil refers to the mass of a volume of dry soil. The volume includes both solids and pores. The bulk density is represented by ρb.

$$\rho b = \frac{\text{weight } of\ oven\ dry\ soil}{total\ soil\ volume}$$

Particle density refers to the mass of solids per volume of the solids alone. These two density measurements provide an important insight into the physical nature of a given soil. Soil density plays a major role both in plant growth and in engineering uses of soil. It is represented by ρp.

$$\rho b = \frac{\text{weight } of\ oven\ dry\ soil}{volume\ of\ soil\ solids}$$

Units of density are typically expressed in g cm-^{3} or mg m-^{3}.

Porosity is the ratio of the volume of the pores in a soil sample to the total volume of the sample. It is represented by φ

$$\varphi = \frac{volume\ of\ pores}{total\ soil\ volume}$$

However, measuring the volume of pores in a soil sample is difficult. In practice, porosity is normally calculated using the formula:

$$\varphi = 1 - (\rho b / \rho p)$$

Porosity is usually expressed as a decimal fraction, but it can also be expressed as a percentage.

Samples for determining bulk density must be collected very carefully to insure the sample represents the *in situ* condition desired and no additional compaction or loosening has occurred.

14.3 REQUIREMENTS

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

- Soil Thermometer
- White card board
- Munsell's colour chart
- Soil bulk density sampler
- Aluminum moisture cans with lids
- Sampling tools like screw, posthole digger, pans etc.
- Analytical balance
- Oven with thermometer 0-1100C

Figure 14.3 : Soil Sieves

14.4 PROCEDURE

Soil Texture: Mechanical sieving method (used when size > 0.05 mm)

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 100 gm 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 its 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 its mass. Record this on your data table.
8. Place the soil collected in sieve #3 on the weighing paper and determine its mass. Record this on your data table.
9. Calculate the relative percent of sand, silt, and clay in the soil sample.
10. Determine the type of soil based on the relative overall percents you calculated.

Alternate method: Soil texture feel method

A soil scientist often needs to estimate soil texture while in the field or when laboratory data on the amounts of sand, silt, and clay are not available. In that case we follow this method:

1. Collect different soil samples.
2. Observe with hand lens. Also examine and observe the soil between thumb and fingers.
3. The following kinds of soils can be observed:
   - Sandy: Individual grains (0.02-2.0 mm) are observed, crystal-like structure.

- Moist sands are squeezed.
- Sandy loam: Dry grains and all separate.
- Moist form does not break and forms casts.
- Loam: Can be squeczed when dry.
- Moist soil forms Casts and can be easily handled without breaking.
- Silt loam: Dry as well as moist soils can be easily handled without breaking.
- Grain size 00.02-0.2 mm.
- Clay loam: Hard when dry. Breaks into lumps. Moist soil 1s pinched forming thin ribbon which breaks easily.
- Clay: Forms a very hard lump when dry. Moist and wet soil sticky. Size of soil particles 0.002 mm.

Detailed feel method is given in the flowchart.

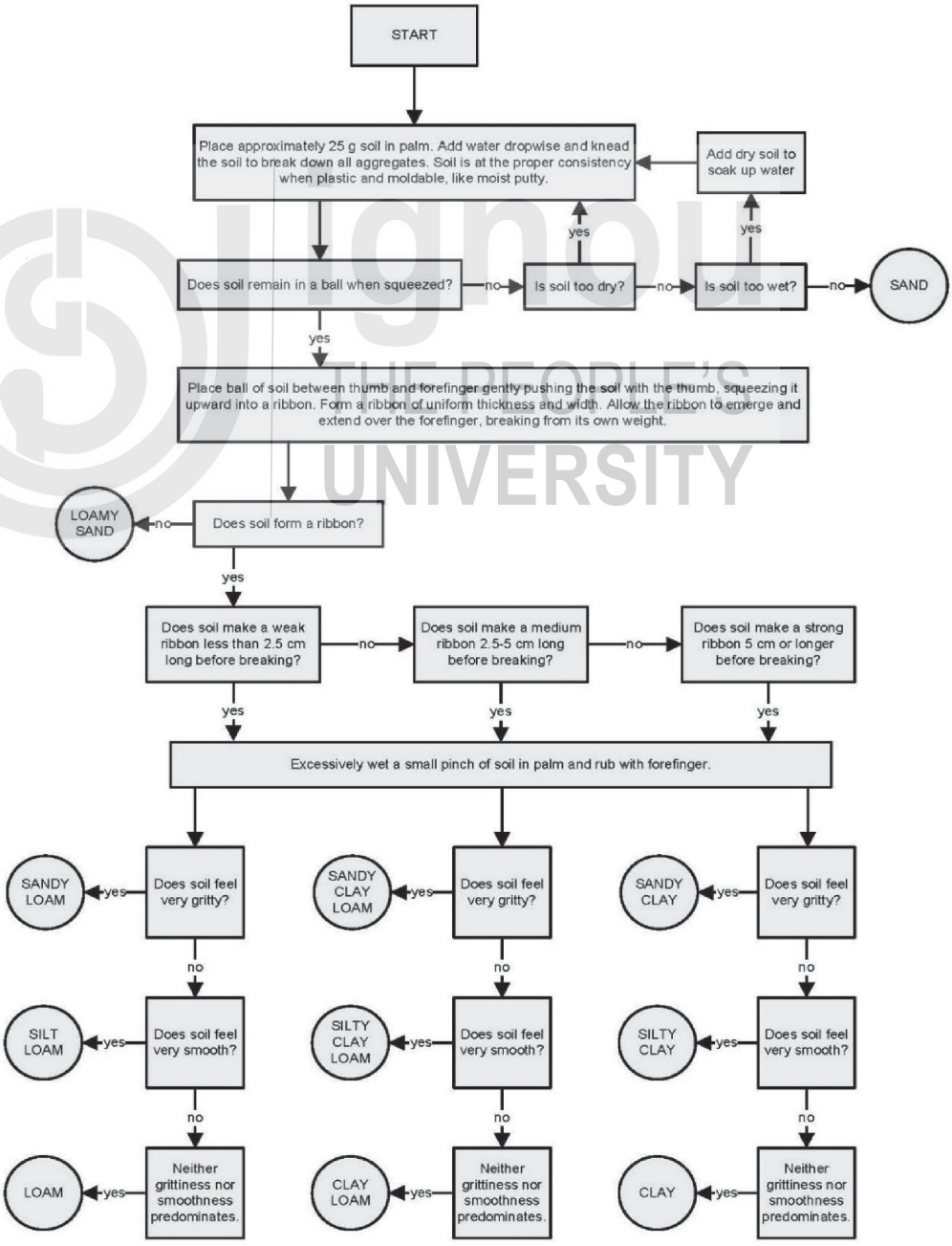


Figure 14.4: Flowchart showing the Textural Feel Method

Soil Colour:

1. Collect soil samples and spread over a cardboard or white paper sheet.
2. Match the colour of different particles with Munsell's colour chart.
3. Note different colours of the soil particles.

Soil Temperature:

1. Dig the soil at different depths such as 1, 6, 12 and 18 inches.
2. Insert the bulb of soil thermometer in soil.
3. Record the temperature.

Bulk Density, Particle Density and Porosity:

1. Insert a 1.5 cm metal ring, a 6 cm metal core, and then a second 1.5 cm metal ring into the barrel of the core sampler, then reattach the barrel to the handle. The sample will be held in the longer cylinder; the two 1.5-cm rings are spacers, which help ensure an undisturbed soil sample.
2. Place the sampler over the desired sampling location, and then drive it into the soil with the slide hammer at the top of the handle. Stop when the cap of the barrel is flush with the soil surface.
3. Remove the sampler from the soil by pushing against the handle until the vertical shaft of the handle is parallel to the soil surface.
4. Remove the barrel from the sampler and gently push the core out of the top of the barrel, taking care to keep the core intact.
5. Carefully cut between the two shorter rings and the main core. Place the core into a labelled, pre-weighed canister, and put on the lid.
6. Back in the lab, weigh each canister plus moist soil.
7. Determine the weight of dry soil in the sample.
8. Measure the length and diameter of the metal cylinders.
9. Use this information to calculate bulk density, porosity, and water-filled pore volume.

Determining the weight of dry soil in the sample:

The simplest method is to dry the sample in a conventional oven:

1. Remove the lids of all of the canisters, and place each in a 105°C oven.
2. Dry overnight.
3. Record the final weight of each canister (including the lid) plus oven-dry soil.
4. Calculate the weight of oven dry soil as in experiment 15

14.5 OBSERVATION AND CALCULATIONS

Note all the necessary readings

1. pH of soil
2. Temperature of soil
3. Texture:
   - Total weight of Soil: T_s gms

- Weight of gravel: W_g gms
- Weight of sand: W_s gms
- Weight of silt: W_{st} gms
- Weight of clay: W_c gms

% Sand = $(W_s / T_s) \times 100$

% Silt = $(W_{st} / T_s) \times 100$

% Clay = $(W_c / T_s) \times 100$

Draw conclusion on type of soil from figure 14.2

4. Bulk density, particle density and porosity

Total soil volume = T_v m^{-3} or cm^{-3}

Weight of moist soil= W_m gms or mg

Weight of oven dry soil = W_d gms or mg

$$\rho = \frac{\text{weight } of \text{ oven dry soil}}{total\ soil\ volume} \quad g\ cm^{-3} \text{ or } mg\ m^{-3}$$

$$\rho p = \frac{\text{weight } of \text{ oven dry soil}}{total\ soil\ volume} \quad g\ cm^{-3} \text{ or } mg\ m^{-3}$$

$$\varphi = 1 - (\rho b / \rho p)$$

14.6 RESULT

Report the following for the given soil sample:

1. Texture:
2. Colour:
3. Temperature:
4. Bulk Density:
5. Particle Density:
6. Porosity:

14.7 PRECAUTIONS

Report the following for the given soil sample:

1. Collect soil sample carefully
2. Do not take the surface soil for analysis. Take soil from at least a depth of 5cm
3. Take care in recording the weight of soil.
4. Be careful while handling the oven.
5. Insert the thermometer at appropriate depth for temperature measurement
6. Note that total volume of the soil sample in bulk and particle density equals the volume of the solids and the volume of the pores.

EXPERIMENT 15

DETERMINATION OF SOIL MOISTURE CONTENT.

Soil moisture is a measure of the water retention of a soil. It is dependent on the organic matter and clay content of the soil, both of which bind up water. So it is a relative measure of those two constituents. Capillary action of the fine grains of the soil can also hold water.

The fact that soils hold water (moisture) is due to their colloidal properties and aggregation qualities. The water is held on the surface of the colloids and other particles and in the pores. The forces responsible for retention of water in the soil after the drainage has stopped due to surface tension and surface attraction and are called surface moisture tension. This refers to the energy concept in moisture retention relationships. The force with which water is held is also termed as suction.

Compared to other components of the hydrologic cycle, the volume of soil moisture is small; nonetheless, it is of fundamental importance to many hydrological, biological and biogeochemical processes.

The amount of soil moisture is important to know because:

- Soil water serves as a solvent and carrier of food nutrients for plant growth
- The yield of a crop is more often determined by the amount of water available rather than the deficiency of other food nutrients
- Soil water acts as a nutrient itself
- Soil water regulates soil temperature
- Soil forming processes and weathering depend on water
- Microorganisms require water for their metabolic activities
- Soil water helps in chemical and biological activities of soil
- It is a principal constituent of the growing plant
- Water is essential for photosynthesis
- It 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 moisture also strongly affects the amount of precipitation that runs off into nearby streams and rivers.
- It also plays an important role in the development of weather patterns and the production of precipitation.

There are different methods by which soil moisture can be measured. The most common method is the gravimetric method based on oven drying. Other methods include:

a. **Gravimetric method with drying by burning Alcohol or spirit:** In this method, the soil moisture is evaporated by igniting the soil mass with alcohol or spirit. The process is repeated to get constant weight of ignited soil.

b. **Direct method by use of neutron moisture probe:** In this method, the soil moisture status is determined *in situ* without disturbing the system. The neutron moisture meter is such a device which is much used in the field for measuring water content.

15.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain the concept of soil moisture
- Know the importance of soil moisture
- Know the different methods of determining soil moisture

15.2 PRINCIPLE

Gravimetric method of moisture estimation based on oven drying is the simplest and most widely used method for measuring soil moisture. Here, the soil sample is placed in an oven at 105^{O} C and dried to a constant weight. The difference in weight is considered to be water present in the soil sample. It is based on the principle that the water in the porous material is lost by evaporation on heating and the porous material undergoes an equivalent loss in its weight. However, the water loss may be limited by the internal operation within the complex porous material such as soil. This method is simple, reliable, inexpensive, and easy to use. The major limitations of this method are that it is laborious and time consuming.

Soil moisture is normally expressed as percentage on weight basis (gm of water per 100 gm of oven dry soil). It can, however, be expressed on volume basis.

Moisture on dry weight basis Mw = Wm/Ws × 100

Moisture on volume basis Mv = Vm/Vs × 100

Where, Wm = Weight of moisture box in gm

Ws = Weight of oven dry soil

Vm = Volume of moisture in cubic cm

Vs = Volume of soil in cubic cm

15.3 REQUIREMENTS

- Aluminum moisture cans with lids
- Sampling tools like screw, posthole digger, pans etc.
- Analytical balance
- Oven with thermometer 0-110^{O} C

15.4 PROCEDURE

1. Take weight of empty moisture box with lid on the physical balance.
2. Draw soil samples from the desired depth with suitable sampling tools and quickly transfer them to pre-weighed moisture can with tight-fitted lid.
3. Record the weight of the can with the moist soil as early as possible.
4. Open the lid and place the can containing the soil in the oven at 105°C for 24 hrs.
5. Remove the can from the oven and cover it with lid immediately and allow it to cool.
6. Weigh the can containing the oven-dry soil along with the lid.
7. Calculate the moisture content on oven-dry basis as per the formula given.

15.5 OBSERVATION AND CALCULATION

Weight of empty box with lid = Xg

Weight of box + lid + moist or air dry soil = Yg

Weight of box + lid + oven dry soil = Zg

Weight of water loss during drying A = (Y-Z)g

Weight of oven dry soil B = (Z-X)g

Percentage moisture by dry weight = (A/B) ×100

15.6 RESULT

The moisture % in the given sample was found to be.....

15.7 PRECAUTIONS

1. Do not take the surface soil for analysis. Take soil from at least a depth of 5cm
2. Take care in recording the weight of soil.
3. Be careful while handling the oven.

EXPERIMENT 16

DETERMINATION OF SOIL pH AND ELECTRICAL CONDUCTIVITY

pH: The pH is defined as the negative logarithm of the active hydrogen ion (H+) concentration. Mathematically, it is expressed as:

pH = - log a H+

Determination of soil pH is actually the measurement of hydrogen ions activity in soil-water system. The pH value of a soil is an indication of soil reaction i.e. soil, acidity, alkalinity or neutrality. It is a simple but very important estimation for soils, since soil pH influences the availability of nutrients to crops. The nutrient availability is governed by soil reaction and is maximum at neutral pH and decreases with increase in acidity or alkalinity. Thus, pH value gives an idea about the availability of nutrients to plants. Soil pH also affects microbial population in soils. Most nutrient elements are available in the pH range of 5.5 to 6.5. In various chemical estimations, pH regulation is critical.

Electrical Conductivity (EC): The knowledge of total soluble salts is essential in crop production, specially during the process of salinization. Since, there is a direct relationship between the quantity of soluble salts and the electrical conductance hence soluble salts in soils are measured indirectly by measuring the electrical conductance of the soil.

The electrical conductivity (EC) is a measure of the ionic transport in a solution between the anode and cathode. This means, the EC is normally considered to be a measurement of the dissolved salts in a solution. Like a metallic conductor, they obey Ohm's law. Since the EC depends on the number of ions in the solution, it is important to know the soil/water ratio used. The EC of a soil is conventionally based on the measurement of the EC in the soil solution extract from a saturated soil paste, as it has been found that the ratio of the soil solution in saturated soil paste is approximately two-three times higher than that at field capacity. As the determination of EC of soil solution from a saturated soil paste is cumbersome and demands 400-500 gm soil sample for the determination, a less complex method is normally used. Generally a 1:2 soil/water suspension is used.

16.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain and define the concept of soil pH and electrical conductivity
- Know the importance of soil pH and electrical conductivity
- Know the method to determine soil pH and electrical conductivity

16.2 PRINCIPLE

The pH is usually measured by pH meter, in which the potential of hydrogen ion indicating electrode (glass electrode) is measured potentiometrically against calomel saturated reference electrode which also serves as salt bridge. Now-a-days, most of the pH meters have single combined electrode. Before measuring the pH of the soil, the instrument has to be calibrated with standard buffer solution of known pH. Since, the pH is also affected by the temperature, hence, the pH meter should be adjusted to the temperature of the solution by temperature correction knob.

The measurement of electrical conductivity (EC) is based on the principle that ions being the carriers of electricity the electrical conductivity of a solution increases with soluble salt concentration. Thus, it is possible to measure electrical conductivity of a soluble salt. The electrical conductivity is measured with the help of solubridge. The instrument is calibrated and cell constant is determined with the help of 0.1 N KCl solution. This solution gives an electrical conductance of 1.41 mmhos/cm or dSm-1 at 25°C.

16.3 REQUIREMENTS

Apparatus

pH meter with a range of 0-14 pH

Electrical conductivity meter (EC meter)

Pipette

Beakers

Conical flask

Glass rod

Filter paper

16.4 SOLUTIONS PROVIDED

i. Distilled water

ii. Standard buffer solutions of pH 4.0, 7.0 or 9.2: They are prepared by dissolving one standard buffer tablet in 100 ml distilled water. It is necessary to prepare fresh buffer solution after few days. In absence of buffer tablet, a 0.05 M potassium hydrogen phthalate solution can be used which gives a pH of 4.0 (Dissolve 10.21 g. of A.R. grade potassium hydrogen phthalate in distilled water and dilute to 1 litre. Add 1 ml of chloroform or a crystal of thymol per litre as a preservative).

iii. Calcium chloride (CaCl2) solution (0.01M): Dissolve 14.7 gm CaCl2.2H2O in 10 litre of water to obtain 0.01M solution.

iv. 0.01M Potassium chloride (KCl) solution: Weigh 0.7456 gm of KCl and dissolve it in distilled water and make the volume to one litre. This solution gives an electrical conductivity of 1411.8x10-3 i.e. 1.412 mS/cm at 25^{O} C. For best result, select a conductivity standard (KCl solution) close to the sample value.

16.5 PROCEDURE

Procedure for pH

1. Calibrate the pH meter, using 2 buffer solutions, one should be the buffer with neutral pH (7.0) and the other should be chosen based on the range of pH in the soil. Take the buffer solution in the beaker. Insert the electrode alternately in the beakers containing 2 buffer solutions and adjust the pH. The instrument indicating pH as per the buffers is ready to test the samples

2. Method 1: Take 20 gm soil in 100 ml beaker and add 40 ml. of distilled water to it. The suspension is stirred at a regular interval for 30 minutes. Determine the pH by immersing electrodes in suspension. For soils containing high salts, the pH should be determined by using 0.01M calcium chloride solution.

3. Method 2: Add small amount of distilled water to 250 gm of air dried soil. Stir the mixture with a spatula. At saturation, the soil paste glistens and flows slightly when the container is tapped it slides freely and ensures cleanly off the spatula. After mixing, allow the sample to stand for an hour. If the paste has stiffened markedly or lost its glistening, add more water or if free water has collected on the surface of the paste, add an additional weighed quantity of dry soil and mix it again. Then insert the electrode carefully in the paste and measure the pH.

Procedure for electrical conductivity

1. Take 40 gm soil into 250 ml conical flask, add 80 ml of distilled water, stopper the flask and shake on reciprocating shaker for one hour. Filter through Whatman No.1 filter paper. The filtrate is ready for measurement of conductivity.
2. Wash the conductivity electrode with distilled water and rinse with standard KCl solution.
3. Pour some KCl solution into a 25 ml beaker and dip the electrode in the solution. Adjust the conductivity meter to read 1.412 mS/cm, corrected to $25^{O}C$.
4. Wash the electrode and dip it in the soil extract.
5. Record the digital display corrected to $25^{O}C$. The reading in mS/cm of electrical conductivity is a measure of the soluble salt content in the extract, and an indication of salinity status of this soil (Table 16.2). The conductivity can also be expressed as mmhos/cm.

16.6 OBSERVATIONS AND CALCULATIONS

Record the pH from the pH meter display and rate the soil as per the given table 16.1

Table 16.1: Based on soil pH values, following types of soil reactions are distinguished:

PH Range	Soil Reaction Rating
<4.6	Extremely acid
4.6-5.5	Strongly acid
5.6-6.5	Moderately acid
6.6-6.9	Slightly acid
7.0	Neutral
7.1-8.5	Moderately alkaline
>8.5	Strongly alkaline

Record the EC from the display and interpret about the soil as per the given table 16.2

TABLE 16.2 General interpretation of EC values

Soil	EC (mS/cm)	Total salt content (%)	Crop reaction
1. Salt free	0-2	<0.15	Salinity effect negligible, except for more sensitive crops

2. Slightly saline	4-8	0.15-0.35	Yield of many crops restricted
3. Moderately saline	8-15	0.35-0.65	Only tolerant crops yield satisfactorily
4. Highly saline	>15	>0.65	Only very tolerant crops yield satisfactorily

16.7 RESULT

The soil pH of the given soil sample was found to be _____ and the soil reaction rating was _____

The electrical conductivity of the soil sample was found to be _____ mS/cm

16.8 PRECAUTIONS

1. Prior to reading, calibrate the pH meter with buffer solutions
2. Buffer solutions should not be stored for too long.
3. Be careful while using chemicals.
4. Drying changes the soil pH. For convenience, the air-dried soil samples are used for pH determination. In soil testing report, whether the dried or field moist samples were used must be mentioned.
5. The pH value in soil-water suspension increases with increasing dilution. The soil:water ratio may vary from 1:1, 1.0:2.5, 1:5 and 1:10. Therefore, in soil testing report the ratio of soil:water should also be mentioned.
6. The supernatant solution of soil:water suspension used for pH determination can be used for electrical conductivity measurement.
7. Soil: water ratio and type of soil used (air dry/moist) must be mentioned in the report.

EXPERIMENT 17

DETERMINATION OF SOIL ORGANIC CARBON

Soil carbon is probably the most important component in soils as it affects almost all soil properties. Estimation of total organic carbon is used to assess the amount of organic matter in the soil. It alters the physical, chemical, and biological properties of soils. Soil organic matter refers to all decomposed, partly decomposed and undecomposed organic materials of plant and animal origin and it is a primary indicator of soil quality. Improvements in soil organic matter create a more favourable soil environment, leading to increases in plant growth. Higher soil organic matter levels cause the soil to retain more water that results in better crop yields, reduces soil erosion, increases plant nutrient retention and increases biological diversity. Soil organic carbon contributes to the cation exchange capacity of a soil. These cation exchange sites are important for retention of nutrients such as calcium, magnesium and potassium. Soil organic carbon often also provides binding sites for many anthropogenic organo chemicals, thus minimizing leaching of hazardous chemicals through the soil profile or making them less bioavailable, which reduces toxicity. Increased soil organic carbon enhances the biomass and diversity of the soil biota. Since the soil microbial community drives many of the nutrient transformations in soil, plant nutrient availability is often enhanced with the increase in microbial biomass and microbial activity of the soil.

The range of organic carbon in majority of mineral surface soils is from 1.2 to 3.5%. Since soil organic matter averages about 58% carbon, it follows that soils generally range from about 2 to 6 % in organic matter. There is also a close relationship between carbon and nitrogen in soils. Most organic matter average about 5% nitrogen so that the N : C ratio is 1:11.6. Therefore, by multiplying the soil organic matter percentage by 0.05 an approximate value for the soil nitrogen percentage is obtained. In soil the chief source of some of the nutrients essential for plant growth is organic matter, such nutrients are N, S and boron.

Organic matter estimation in the soil can be done by different methods. Loss of weight on ignition can be used as a direct measure of the organic matter contained in the soil. It can also be expressed as the content of organic carbon in the soil. The most appropriate method for organic carbon estimation is Walkley and Black method which can be performed both volumetrically and colorimetrically.

17.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Explain about the soil organic carbon
- Explain the methodology of estimating the soil organic carbon
- Know the importance of soil organic carbon and soil organic matter
- Know the relationship between soil organic carbon, nitrogen and soil organic matter

17.2 PRINCIPLE

This protocol applies to the determination of the Oxidizable Organic Carbon content in soil. Organic carbon content is calculated from the amount of chromic ion ($Cr^{3}+$) formed, using a titration or colorimetric method.

The determination of soil organic carbon is based on the Walkley-Black chromic acid wet oxidation method. A suitable quantity of the soil is digested with chromic acid and Sulphuric acid making the use of heat of dilution of Sulphuric acids soil is digested and organic matter of the soil is oxidized. Excess of chromic acid left over unreduced by the organic matter of the soil is determined by a titration with standard Ferrous Ammonium Sulphate solution using diphenylamine as indicator. Oxidizable organic carbon in the soil is oxidised by 0.167 M potassium dichromate ($K_2Cr_2O_7$) solution in concentrated sulfuric acid. The heat of reaction raises the temperature which is sufficient to induce substantial oxidation. Oxidisable matter in the soil is oxidised by 1N $K_2Cr_2O_7$ solution. The reaction is assisted by the heat generated by the reaction of two volumes of sulphuric acid (H_2SO_4) with one volume of the dichromate. The remaining dichromate is titrated with ferrous sulphate. The titre is inversely related to the amount of C present in the soil sample. The chromic acid in the presence of excess H_2SO_4 is used as an oxidizing agent for oxidizable organic matter of the soil. The heat of dilution of H_2SO_4 works as a standardized ferrous sulphate solution.

Chemical reaction is as follows:

$$2Cr_2O_7^{2-} + 3C^0 + 16H+ \longrightarrow 4Cr^{3}+ + 3CO_2 + 8H_2O$$

1 ml of 1 N dichromate solution is equivalent to 3 mg of carbon. After the reaction, the excess Cr_2O_7 is titrated with 0.5 M $FeSO_4$ or 0.5 M $(NH_4)2\ Fe(SO_4)2.6H_2O$

$$6\ Fe^{2}+ + Cr_2O7^{2-} + 14\ H^{+} \longrightarrow 2Cr^{3}+ + 6Fe^{3}+ + 7H_2O$$

$$4\ Cr^{6}+ + 3C \longrightarrow 4Cr^{3}++ 3C^{4}+$$

$$2H_2Cr_2O_7+ 3C+6\ H_2SO_4 \longrightarrow 2Cr_2\ (SO_4)_3 + 3CO_2 +8\ H_2O$$

$$K_2Cr_2O_7 + 4\ H_2SO_4 \longrightarrow K_2SO_4+ 2Cr2\ (SO_4)_3 + H_2O +3O$$

$$2FeSO_4 + H_2SO_4+O \longrightarrow Fe_2\ (SO_4)_3 + H_2O$$

The $Cr_2O_7^{2}$- reduced during the reaction with soil is proportional to the oxidisable organic C present in the sample. The organic carbon can then be estimated by measuring the remaining unreduced dichromate by back-titrating with ferrous sulphate or ammonium ferrous sulphate using diphenylamine or o-phenanthroline-ferrous complex as an indicator.

Alternately the organic carbon can be calculated from the amount of chromic ion (Cr_3+) formed, using a colorimetric procedure measuring absorbance at 588 nm. An advantage of this procedure over the titrimetric method is that accurate standardisation of the $Cr_2O_7^{2-}$ solution is not required.

17.3 REQUIREMENTS

Apparatus

Oven

Analytical balance

Measuring cylinder

Burettes 50 ml,

Pipettes

Conical flasks, 500 ml

Beakers; 100 ml, 250 ml

Glass dropper

Glass rod

Burette stand

17.4 SOLUTIONS PROVIDED

i. Distilled water

ii. Potassium Dichromate Standard, 0.167 M (1.0 N): Dissolve 49.04 gm of analytical grade $K_2Cr_2O_7$ (previously dried at 105°C for 2 hours and cooled in a dessicator to room temperature) in distilled water, and dilute the solution to a volume of 1000 ml.

iii. Sulfuric Acid, Concentrated (not less than 96%): Add Ag_2SO_4 to the acid at the rate of 15 gm per liter.

iv. Phosphoric Acid, 85% (The phosphoric acid is added to form a complex with the interfering iron (III), providing a sharper color change of the indicator).

v. Sodium fluoride 2%

vi. Ferrous Ammonium Sulphate (FAS), 0.5 M Dissolve 196 gm of analytical grade $(NH_4)_2$ $Fe(SO_4)2.6H_2O$ in 800 ml of distilled water, add 20 ml of concentrated sulfuric acid, cool the solution, and dilute it to a volume of 1000 ml with distilled water. The Fe^{2+} in FAS oxidizes slowly on exposure to air so it must be standardized against the dichromate daily. Prepare a new solution every 30 days.

vii. Diphenylamine to be used as indicator – Dissolve 0.5 gm in 20cc water and add 100 ml conc. H_2SO_4.

17.5 PROCEDURE

1. Air dry the soil sample and sieve to ≤ 2.0 mm size.
2. Weigh 1.0 g of air dried into a 500 ml conical flask.
3. Add 10 ml of 1N $K_2Cr_2O_7$ and swirl the flask gently to disperse the soil in the solution.
4. Then with care, rapidly add 20 ml concentrated H_2SO_4, directing the stream into the suspension.
5. Immediately swirl the flask gently until soil and reagents are mixed, then more vigorously for a total of 1 min. and allow the reaction to proceed for 30 minutes.
6. Add 200 ml of water to the flask
7. Then add 10 ml of 85% H_3PO_4 and 10 ml of NaF solution.
8. Add 2 ml of diphenylamine indicator
9. Titrate the solution with 0.5 M FAS solution
10. At the end-point the color changes sharply to brilliant green.
11. Determine the blanks in the same manner, but without soil, to standardize the $K_2Cr_2O_7$.
12. Compute for the %OC with the computation as given.

17.6 OBSERVATIONS AND CALCULATIONS

Observation Table

S.No.	Volume of FAS used (Burette reading in ml)		Final Volume of FAS used (in ml) $Vsample$
	Initial Reading (in ml)	Final Reading (in ml)	
1.			
2.			
3.			
4.			

Calculation

The % organic carbon is determined by the following formula:

$$Organic\ C,\% = \frac{0.003\ \text{g} \times \text{N} \times 10\ \text{ml} \times (1 - \{Vblank/Vsample\}) \times 100}{W}$$

where:

$Vblank$ = volume of FAS used in blank, ml

$Vsample$ = volume of FAS used in sample, ml

N= Normality of $K_2Cr_2O_7$

W = weight of soil, gm

Note: The % organic carbon limits are as follows

Low : < 0.5%

Medium : 0.5 – 0.75%

High : > 0.75%

17.7 RESULT

The % organic carbon in the given sample was found to be _____

17.8 PRECAUTIONS

1. Safety glasses, gloves and lab coats must be worn when handling any chemicals
2. All titrations and handling of chemicals should be done carefully.
3. Keep away from naked flames/heat.
4. Do not discharge the waste into the drain.
5. Never dilute by pouring water into the acid. Always add the acid to the water.
6. Wash hands and clean other exposed areas with mild soap and water after using all chemical reagents.

EXPERIMENT 18

DETERMINATION OF TOTAL KJEHLDAHL NITROGEN (TKN) AND AMMONICAL NITROGEN

The Earth's atmosphere comprises of about 78% nitrogen but it has limited availability for biological use which leads to a scarcity of usable nitrogen in different types of ecosystems. Nitrogen gets converted into different usable chemical forms and is circulated among the hydrosphere, atmosphere and lithosphere by an effective biogeochemical cycle of nitrogen. This conversion of nitrogen is carried out through both biological and physical processes. Thus, the nitrogen availability depends on the nitrogen cycle which ultimately affects the rate of major ecosystem processes, like primary production and decomposition. Anthropogenic activities like fossil fuel combustion, excess use of artificial nitrogen fertilizers, and release of nitrogen in wastewater dramatically alters the nitrogen cycle. This alteration affects both the environment and human health.

Higher levels of nitrogen in the form of ammonia and ammonium both in soil and water have detrimental effects on plants and aquatic animals, respectively. Water is also subjected to pollution from waste materials, including sewage, which often contains nitrogenous organic compounds and ammonia. Other risks of nitrogen pollution include water acidification; eutrophication of fresh and saltwater systems; and toxicity in animals, including humans. Excessiveuse of N-fertilizer in agriculture has been one of the major sources of nitrate pollution in groundwater and surface water

Further, when present in drinking water, nitrate has been associated with methaemoglobinaemia (blue baby disease) in human infants.

Thus, it is important to estimate nitrogen content in soil and water to know about their quality. Total N includes all forms of inorganic N, like NH4 –N, NO3 -N and also NH2 (Urea) –N, and the organic N compounds like proteins, amino acids and other derivatives. Depending upon the form of N present in a particular sample, specific method is to be adopted for getting the total nitrogen value. While the organic N materials can be converted into simple inorganic ammoniacal salt by digestion with sulphuric acid, for reducing nitrates into ammoniacal form, use of salicylic acid or Devarda's alloy is made in the modified Kjeldahl method. Total nitrogen is estimated by the micro- Kjeldahl method as per procedure suggested by AOAC (1995). Nitrogen in samples like plant and soil exists in a very complicated bonding structure. A known weight of the plant/soil samples in the presence of sulphuric acid with catalyst mixture under high temperature is digested where complicated structures are broken to simple structure, thereby releasing nitrogen in the form of ammonium radical (NH_4+). Then in presence of sodium hydroxide, the released ammonia is condensed and absorbed in known volume of a boric acid with mix indicator to form ammonium borate, the excess of which is titrated with a standard sulphuric acid.

18.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Know about importance of nitrogen
- Know about nitrogen cycle
- Know about Kjeldahl method of estimating total nitrogen

18.2 PRINCIPLE

The Kjeldahl method is used to determine the nitrogen content in organic and inorganic samples. It was developed by a brewer called Johann Kjeldahl in 1883. The protocol is built on the principle that strong acid helps in the digestion of food so that it releases nitrogen which can be determined by a suitable titration technique. The determination of Kjeldahl nitrogen is made in foods and drinks, meat, feeds, cereals and forages for the calculation of the protein content. It is also used for the nitrogen determination in wastewaters, soils and other samples.

The Kjeldahl procedure involves three major steps:

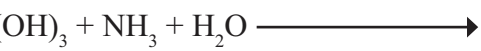
1. Digestion
2. Distillation
3. Titration

1. Digestion: During digestion all the nitrogen bonds are broken and the organically bonded nitrogen is converted into ammonium ions (NH_4+). Organic carbon and hydrogen form carbon dioxide and water. In this process the organic material carbonizes which can be visualized by the transformation of the sample into black foam. During the digestion the foam decomposes and finally a clear liquid indicates the completion of the chemical reaction. For this purpose, the sample is mixed with sulfuric acid at temperatures between 350 and 380 ºC. The higher the temperature used, the faster digestion can be obtained. The speed of the digestion can be greatly improved by the addition of salt and catalysts. Potassium sulfate is added in order to increase the boiling point of sulfuric acid and catalysts are added in order to increase the speed and efficiency of the digestion procedure. Oxidizing agents can also be added to improve the speed even further. After digestion is completed the sample is allowed to cool to room temperature, then diluted with water and transferred to the distillation unit.

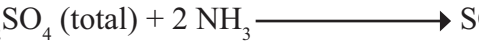
2. Distillation: During the distillation step the ammonium ions (NH4+) are converted into ammonia (NH3) by adding alkali (NaOH). The ammonia (NH3) is transferred into the receiver vessel by means of steam distillation.

The receiving vessel for the distillate is filled with an absorbing solution in order to capture the dissolved ammonia gas.

Common absorbing solutions involve aqueous boric acid [$B(OH)_3$] of 2-4% concentration. The ammonia is quantitatively captured by the boric acid solution forming solvated ammonium ions.



Other acids can also be used as precisely dosed volume of sulfuric acid or hydrochloric acid that captures the ammonia forming solvated ammonium ions.



3. Titration: The concentration of the captured ammonium ions can be determined using two types of titrations:

i. When using the boric acid solution as absorbing solution, an acid-base titration is performed using standard solutions of sulfuric acid or hydrochloric acid and a mixture of indicators. The detection of the end point can be carried out manually or with a colorimetric titration and using a combination of indicators. The combination of methyl red and methylene blue indicators is frequently used in many methods. Depending on the amount of ammonium ions present, concentrations in the range of 0.01N to 0.5N are used. Alternatively, the end point can be determined potentiometrically with a pH-electrode. This titration is called direct titration.

$B(OH)_{4-} + HX \rightleftharpoons X- + B(OH)_3 + H_2O$

HX= strong acid (X= Cl-, etc.)

ii. When using sulphuric acid standard solution as absorbing solution, the residual sulfuric acid (the excess not reacted with NH3) is titrated with sodium hydroxide standard solution and by difference the amount of ammonia is calculated. The end-point is detected using a color indicator. Methyl orange is usually the preferred indicator. This titration is called back titration.

H_2SO_4 (total) + 2 $NH_3 \longrightarrow SO_4^{2-} + 2\ NH_4^+$

18.3 REQUIREMENTS

1. KEL PLUS Automatic Nitrogen Estimation System :

The said instrument is used for determination of nitrogen. It consists of the following;

- **Macro Block Digestion System (Model KES 12L):** This digestion system is suitable for soil, plant, water, pesticides, fertilizers, food and feed samples. It is microprocessor based automatic twelve place macro block digestion system with temperature controller fitted with sensor break protection (Microprocessor based) feature and temperature range from 50-450 0C.
- **Acid Neutralizer Scrubber (Model KEL VAC):** It is used to neutralize the acid fumes, which are absorbed in 15% sodium hydroxide and dissolved in water stored *in the system tank*. After every 2 cycles of digestion, the 15% sodium hydroxide solution is replaced and after 3 cycles of digestion, acid fumes dissolved in water tank is drained off and refilled with fresh water in the system tank.
- **Automatic Distillation System (Model Classic DX):** It is fully automatic distillation system with programmable auto run digital features, with automatic dilution and addition of boric acid and NaOH. Both modes (auto and manual) are available for distillation reagents addition.
- **Refrigerated Water Cooling System for Condenser (Model Kel Freeze):** It is refrigerated water cooling system for distillation and condensing system with inbuilt compressor and recirculator pump.

2. Electronic balance
3. Burette
4. Pipette
5. Conical flask
6. Measuring cylinder
7. Distilled water

18.4 SOLUTIONS PROVIDED

1. Concentrated sulphuric acid (H_2SO_4).
2. Catalyst mixture: Mix with 250 gm potassium sulphate (K_2SO_4), 50 gm cupric sulphate ($CuSO_4$. 5 H_2O) and 5 gm metallic selenium powder in the ratio of 50:10:1.
3. 40 % sodium hydroxide (NaOH).
4. 4 % boric acid containing 20 - 25 ml mixed indicator /liter.
5. Mixed indicator: 0.066 gm methyl red + 0.099 gm bromocresol green dissolve in 100 ml of 95 % alcohol.
6. 0.02N sulphuric acid (H_2SO_4).

18.5 PROCEDURE

1. Preparation of plant and soil samples:

The plant analysis has been considered as a superior diagnostic technique for mineral content. Whole plant is dried in open air for few days after that it was further dried in hot air oven at about 60 ± 2^O C for eight to ten hours per day to achieve complete drying. After drying, whole plant is powdered with the help of a grinder, passed through 2 mm stainless steel sieve and used for chemical assay. The soil sample from definite depth was randomly collected from the field with the help of screw auger. All the possible technical precautions as prescribed for standard soil sampling were also taken. Samples were brought to the laboratory, air-dried in the shade and grounded by wooden roller, thereafter sieved through 2 mm stainless steel sieve and stored in polythene bags and used for chemical assay.

2. Digestion:

i. Weigh 0.5 gm of prepared plant sample or 1 gm of soil sample and transfer it to the digestion tube.

ii. Add 10 ml of concentrated sulphuric acid and 5 gm of catalyst mixture to the sample

iii. Load the digestion tubes in to the digester and heat the digestion block.

iv. Switch on the digestion unit and set the initial temperature 100°C till frothing is over.

v. Then block temperature is raised to 400°C. The effective digestion starts only at 360°C and beyond 410°C.

vi. The sample turns light green colour or colorless at the end of the digestion process.

3. Distillation:

i. After cooling the digestion tube, load the tube in distillation unit and other side of hose keep 20 ml of 4 % boric acid with mixed indicator in 250 ml conical flask.

ii. 40 ml NaOH (40 %) is automatically added by distillation unit programme.

iii. The digested sample is heated by passing steam at a steady rate and the liberated ammonia absorbed in 20 ml of 4 % boric acid containing mixed indicator solution kept in a 250 ml conical flask.

iv. With the absorption of ammonia, the pinkish colour turns to green.

v. Nearly 150 ml of distillate is collected in about 8 minutes.

vi. Simultaneously, blank sample (without plant/soil) is to be run.

4. Titration:

i. The green colour distillate is titrating with 0.02N sulphuric acid and the colour changes to original shade (pinkish color).

ii. Note the blank and sample titer reading (ml) and calculate the total nitrogen content present in plant/soil samples.

Alternate method

1. Weigh 1 gm sample of soil. Place in Kjeldahl flask.
2. Add 0.7 gm copper sulphate, 1.5 gm K_2SO_4 and 30 ml H_2SO_4.
3. Heat gently until frothing ceases. If necessary, add small amount of paraffin or glass beads to reduce frothing.
4. Boil briskly until solution is clear and then continue digestion for at least 30 minutes.
5. Remove the flask from the heater and cool, add 50 ml water and transfer to distilling flask.
6. Take accurately 20–25 ml standard acid (0.1M HCl or 0.1M H_2SO_4) in the receiving conical flask so that there will be an excess of at least 5 ml of the acid.
7. Add 2-3 drops of methyl red indicator. Add enough water to cover the end of the condenser outlet tubes.
8. Add 30 ml of 35% NaOH in the distilling flask in such a way that the contents do not mix.
9. Heat the contents to distil the ammonia for about 30-40 minutes.
10. Remove receiving flask and rinse outlet tube into receiving flask with a small amount of distilled water.
11. Titrate excess acid in the distillate with 0.1M NaOH.
12. Determine blank on reagents using same quantity of standard acid in a receiving conical flask.

18.6 OBSERVATION AND CALCULATIONS

Observation Table

S.No.	Volume of burette (titer) solution used (in ml)		Final volume of titer used (in ml) (B-A)
	Initial reading (A)	Final reading (B)	
Blank			
Sample			

Calculation

The % organic carbon is determined by the following formula:

Nitrogen content in sample (%) = **R** (sample titer-blank titer) x Normality of acid x

$$\frac{\text{Atomic weight of nitrogen x 100}}{\text{Sample weight (g) x 1000}}$$

Calculation for alternate method

$$\text{Percent N} = \frac{1.401 \times (V1N1 - V2N2) - (V3N1 - V4N2) \times df}{W}$$

Where,

V1 - ml of standard acid taken in receiving flask for samples

V2 - ml of standard NaOH used in titration

V3 - ml of standard acid taken to receiving flask for blank

V4 - ml of standard NaOH used in titrating blank

N1 – Normality of standard acid

N2 - Normality of standard NaOH

W - Weight of sample taken

df - Dilution factor of sample (if 1 g was taken for estimation, the dilution factor will be 100).

Note: 1000 ml of 0.1 M HCl or 0.1 M H_2SO_4 = 1.401 gm Nitrogen

18.7 RESULT

The TKN (Total Kjeldahl nitrogen) was found to be _____

18.8 PRECAUTIONS

1. Each chemical should be handled carefully to avoid any hazard.
2. If samples originate from a highly contaminated area, appropriate sample handling procedures must be followed to minimize worker exposure.
3. Maintain the lab protocol to avoid dangers.

IV EXERCISES BASED ON DIFFERENT STATISTICAL ANALYSIS

EXPERIMENT 19

MEASURES OF CENTRAL TENDENCY, MEASURES OF DISPERSION, SKEWNESS AND KURTOSIS

Measures of central tendency: If we consider the heights of mango trees in a forest and arrange them in a frequency distribution, we will find that there are very few plants which have the maximum and minimum height whereas most of the plants have height somewhere between the highest and lowest heights of the plants. Thus, in samples as well as population it is found that the values of any variable tend to concentrate or cluster around some central value which can be taken as a representative for the whole data. This tendency of distribution is known as central tendency and the measures used to consider this tendency are known as measures of central tendencies. Measure of central tendency is also known as statistical average. The measures of central tendency can be defined as sort of average or central value of a series of data which is a representative of the characteristic of the whole data and conveys a fairly adequate idea of the whole data under study.

The most common measure of central tendency are:

i. Airthmetic Mean or Mean

ii. Median

iii. Mode

Airthmetic mean is a mathematical average whereas median and mode are averages of position.

Mean is the simplest measurement of central tendency and is a widely used measure. Mean, also known as arithmetic average, is the most common measure of central tendency and may be defined as the value which we get by dividing the total of the values of various given items in a series by the total number of items. Its chief use consists in summarising the essential features of a series and in enabling data to be compared. It is amenable to algebraic treatment and is used in further statistical calculations. It is a relatively stable measure of central tendency.

Median is the value of the middle item of series when it is arranged in ascending or descending order of magnitude. It divides the series into two halves; in one half all items are less than median, whereas in the other half all items have values higher than median.

Median is a positional average and is used only in the context of qualitative phenomena, for example, in estimating intelligence, etc., which are often encountered in sociological fields. Median is not useful where items need to be assigned relative importance and weights. It is not frequently used in sampling statistics.

Mode is the most commonly or frequently occurring value in a series. The mode in a distribution is that item around which there is maximum concentration. In general, mode is the size of the item which has the maximum frequency, but at items such an item may not be mode on account of the effect of the frequencies of the neighbouring items. Like median, mode is a positional average and is not affected by the values of extreme items. It is, therefore, useful in all situations

where we want to eliminate the effect of extreme variations. Mode is particularly useful in the study of popular sizes.

Measures of Dispersion: Measure of dispersion is the deviation of the individual values around the central value of a data. It is the measure of variation of the items and therefore also called as measure of variation. Averages can represent a series only as best as a single figure can, but it certainly cannot reveal the entire story of any phenomenon under study. Specially it fails to give any idea about the scatter of the values of items of a variable in the series around the true value of average. In order to measure this scatter, statistical devices called measures of dispersion are calculated. Important measures of dispersion are (a) range, (b) mean deviation, and (c) standard deviation.

Range is the simplest possible measure of dispersion and is defined as the difference between the lowest value and highest value of a series.

Mean deviation is the average of difference of the individual values of items from the mean. It is also called as average deviation. Such a difference is technically described as deviation. It is denoted by MD.

Standard deviation is most widely used measure of dispersion of a series and is commonly denoted by the symbol 'μ' (pronounced as sigma). Standard deviation is defined as the positive square-root of the average of squares of deviations obtained from the arithmetic average.

Skewness: A symmetrical distribution when plotted on a graph gives a perfectly bell shaped curve. Such a distribution is called normal distribution and the curve is called a normal curve. In this case the mean, median and mode are identical or they coincide. Such a distribution can be divided into 3 parts; the right tail, middle part and the left tail. In symmetrical distribution left and right tails are of equal length but in asymmetrical distribution one of the tail is longer than the other. Such a distribution is called skewed distribution (Figure 19.1). Thus, skewness is the measurement of asymmetry. In a skewed distribution, mean, median and mode do not coincide and are pulled apart. If the curve of the distribution has a longer tail towards right hand side, it is positive skewness and here Mean>Median>Mode.

If the curve of the distribution has a longer tail towards left hand side, it is negative skewness and here Mean<Median<Mode.

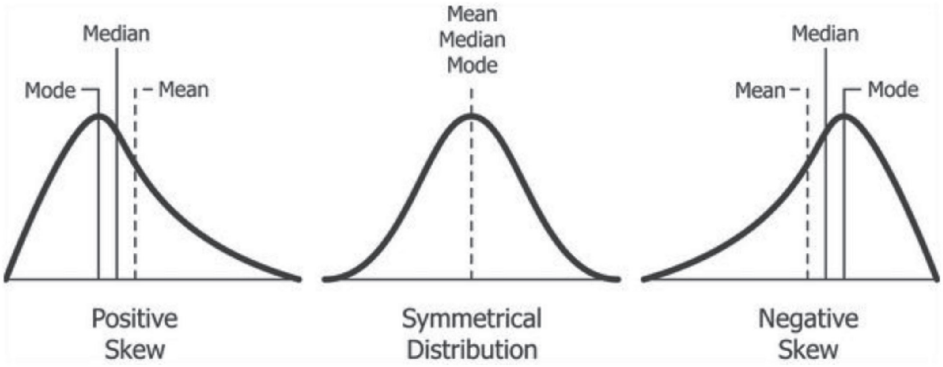


Figure 19.1: Symmetrical and skewed distribution

Measures of skweness indicate the extent of skweness as well as direction. These measures can be absolute or relative. Absolute measures do not give comparative values. Relative measures help in comparison of two different distributions and are known as coefficient of skewness.

The important coefficient of skewness is:

i. Karl Pearson's coefficient of skewness

ii. Bowley's coefficient of skewness

iii. Kelly's coefficient of skewness

iv. Coefficient of skewness based on moments

Kurtosis: Kurtosis refers to the flatness of the frequency distribution. It gives an idea of the shape and nature of the frequency distribution. Karl pearson called it as measure of convexity. Kurtosis refers to the degree of peakedness of the hump of a distribution. A normal distribution curve or a bell shaped curve is called mesokurtic; a curve is more peaked than the normal curve is called leptokurtic and a flattened curve is called platykurtic (Figure 19.2).

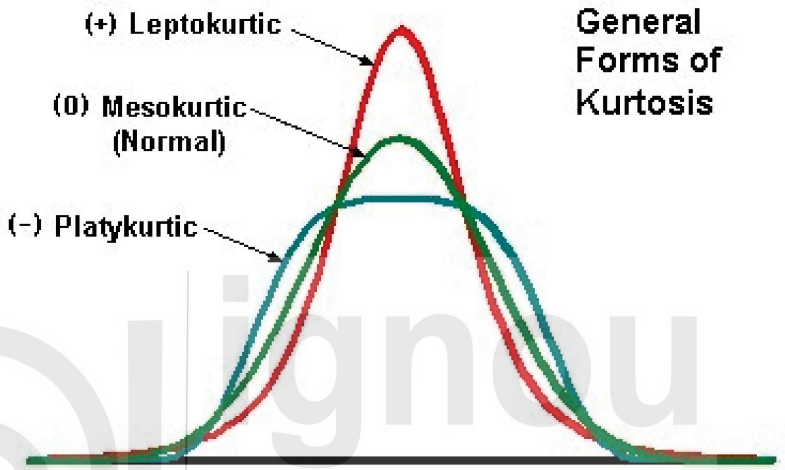


Figure 19.2: General forms of kurtosis

19.1 OBJECTIVES

After studying and performing this experiment you must be able to:

- Know and calculate different measures of central tendencies
- Know and calculate different measures of dispersion
- Know and calculate skewness
- Know and calculate kurtosis

19.2 PRINCIPLE

1. Measures of Central Tendencies

i. Airthmetic mean

Airthmetic mean is represented by μ or X

$$\mu = \frac{\text{Sum of all observations}}{\text{Total number of observations}}$$

For Raw data

$$\mu = \frac{\Sigma xi}{n}$$

where

$\sum x_i$ = Summation of all the observations

N = total number of observations

For frequency distribution

$$\mu = \frac{\Sigma f_i x_i}{\Sigma f_i} = \frac{f_1x_1+f_2x_3+.....f_nx_n}{f_1+f_2+f_3+.....f_n}$$

where

$\sum$ = Summation

f_ix_i = Product of all individual observation with their respective frequency

$\sum f_i$ = n or Summation of all the frequencies

Note: in case of continuous or grouped frequency distribution with class intervals the value of x_i is taken as the mid value of corresponding class.

ii Median

Median is represented by Md

For calculating median arrange the data in ascending or descending order

For ungrouped data and frequency distribution

1. If n=odd

Md = Value of $(\frac{n+1}{2})^{th}$ item

2. If n= even

$$Md = \frac{\text{Value of } (\frac{n}{2})^{th} \text{ item} + \text{Value of } (\frac{n+1}{2})^{th} \text{ item}}{2}$$

For grouped data with class interval

$$Md = L + \frac{\frac{n}{2}+cf}{f} \times h$$

Where

L= Lower limit of median class

n= total frequency

cf= cumulative frequency prior to the median class

h= width of class interval of median class

F= frequency of median class

(Note: The median class is determined as for ungrouped data considering n as even or odd)

iii Mode

Mode is that individual variable which occurs most frequently in the distribution. The individual variable with highest frequency is the mode of the distribution. It is denoted by M or Z.

For grouped distribution with class interval

Mode = L + × h

Where

L= Lower limit of modal class (class with highest frequency)

Δ_1 = the difference between the frequency of modal class and the frequency of preceeding modal class

Δ_2 = the difference between the frequency of modal class and the frequency of succeeding modal class

h= width of class interval of modal class

2. Means of dispersion

i. **Range** = largest value- smallest value

ii. **Mean Deviation MD**

For ungrouped data

MD =

For grouped data

MD =

Where

D = deviation of individual observation from mean ($\mu - x_i$)

F is frequency of each observation

N = total number of observation

iii. Standard deviation SD or σ

For ungrouped data

SD or σ =

For grouped data or frequency distribution

SD or σ = or

Where

xi = Individual observation

μ = Mean

fi = frequency of individual observation

n= $\sum f_i$ = total number of observations

3. Skewness

i. Karl Pearson's coefficient of skewness

Sk (Karl) =

Its value lies between ± 1

When its value is zero it is a symmetrical distribution and there is no skewness

When its value is negative the distribution is negatively skewed

When its value is negative the distribution is positively skewed

If mode is not distinct or ill defined, then

Sk (Karl) =

ii. Bowley's coefficient of skewness

Sk (Bowley) =

Where Q1= First quartile and Q3= Third quartile

iii. Kelly's coefficient of skewness

Sk (Kelly) =

iv. Coefficient of skewness based on moments (β1)

4. Kurtosis

Karl pearson gave the coefficient of Kurtosis as coefficient of Beta two (β2)

β2 =

μ2 = Second moment = or

μ4 = Fourth moment = or

when

β2 = 3 it is mesokurtic

β2 > 3 it is leptokurtic

β2 < 3 it is platykurtic

19.3 EXERCISE

1. Find the mean, median and modal height of 30 plants from the given data:

Height in cms	70	50	60	52	65	75	68
No. of plants	3	5	7	6	2	3	4

Answers: mean: 60.63 cm, median= 60, mode= 60

2. Calculate the mean, median and mode of the following data

No. of fruits per plant	5-15	15-25	25-35	35-45	45-55	55-65
No. of plants	4	7	12	9	5	3

Answers: Mean= 33.25; median =32.5; mode= 31.25

3. Find the mean deviation and standard deviation

Weight of fruits	2-2.9	3-3.9	4-4.9	5-5.9	6-6.9
No. of plants	6	13	11	8	12

Answers: Mean deviation: 1.168; Standard deviation: 1.35

4. From the given data of production from 2 farms calculate the Karl Pearson and Bowley coefficient of skewness

Measure	Farm A	Farm B
Mean	150	140
Median	142	155
Standard Deviation	30	55
Third Quartile	195	260
First Quartile	62	80

Answers: Sk (Karl)= -0.2; Sk (Bowley)=0.17

5. Find kurtosis in the given data: 4, 5, 2, 7, 2

Answer = -1.24

EXPERIMENT 20

CORRELATION AND REGRESSION ANALYSIS; ANALYSIS OF VARIANCE

Correlation analysis

In many kinds of data, the 2 variables under study are dependent on each other. In such a case, the magnitude of one of the variables changes as the magnitude of the other variable changes. Such a relation is called correlation. The term correlation was first given by Auguste Bravais and its graphical form was given by Francis Galton. Correlation Analysis is the study of relationship between two variables. Correlation is basically of two types:

1. **Positive or direct correlation:** It implies that for an increase in the value of one variable the other variable also increases or a decrease in one variable will result in decrease in the value of other variable. Thus the two variables move together in the same direction.
2. **Negative or indirect correlation:** It implies that increase in the value of one variable is accompanied by decrease in the value of other variable or vice versa. Thus, the two variables tend to move in opposite direction.

In both the cases if the change between the two variables is constant it is called linear correlation and if the change is not constant it is non linear correlation. Visually correlation is shown as scatter diagram.

Scatter diagram is a convenient way of displaying correlation but it does not give idea about the extent of correlation in terms of magnitude. To measure correlation, Karl Pearson introduced the correlation coefficient. It is denoted by r or γ.

or

where

r or γ = Karl Pearson correlation coefficient

x and y are two variables

μx and μy are their respective means

Deviation from means : dx= x- μx and dy= x- μ_y

The value of r or γ ranges from +1 to – 1

Negative value of r or γ represents negative correlation

Positive value of r or γ represents positive correlation

If r or γ= 0 then there is no correlation

The degree of correlation or the relationship between two variables is known as given in the table 20.1

Degree of Correlation	Value of r or γ	
	Positive	Negative
Perfect	+1	-1
High level	+0.75 to +1	-0.75 to -1
Moderate level	+0.25 to +0.75	-0.25 to -0.75
Low level	0 to +0.25	0 to -0.25
Zero	r or γ= 0	

Regression analysis

The term regression was first given by Sir Francis Galton. Blair defined regression as a measure of the average relationship between two or more variables in terms of original units of data. The estimation of regression is called regression analysis where two variables are involved. One variable is called dependent variable and the other is the independent variable. For e.g. Crop yield and rainfall are related variables where yield is dependent variable and rainfall is the independent variable. The value of dependent variable can be calculated or estimated from the value of independent variable. Thus Regression analysis attempts to establish and study the function and nature of the relationship between the variables and provides a mechanism for predicting or forecasting. It also finds the cause and effect relationship. Regression finds the best estimate of line which means an average line which gives the best estimate. The graphical representation of regression is called regression lines.

There are two regression lines

i. Regression line of X on Y (here X is dependent variable and Y is independent Variable)

ii. Regression line of Y on X (here Y is dependent variable and X is independent Variable)

Algebraic expression of the regression line is called regression equation. Regression equation is the expression of relationship between the independent variable and dependent variable expressed in a mathematical form.

For the two regression lines there are two regression equations

i. Regression equation of X on Y

$X = a + bY$

ii. Regression equation of Y on X

$Y = a + bX$

where a and b are constants; a represents the intercept that is the distance between the point of origin and the point where the regression line touches the Y axis. The constant b shows the slope of line or the regression coefficient.

The values of a and b are found with the help of normal equations

General equation	$X = a + bY$	$Y = a + bX$
Normal equations	$\sum X = na + b\sum Y$ $\sum XY = a\sum Y + b\sum Y^2$	$\sum Y = na + b\sum X$ $\sum XY = a\sum X + b\sum X^2$

Where n is the total number of observation

Alternate method to calculate regression coefficient

1. Regression equation of X on Y

$X = a + bY$

The regression coefficient of X on Y is denoted as bxy or b_1

b_{xy} or b1 = or

where

γ is correlation coefficient

= Standard deviation of x

= Standard deviation of y

μx and μy are the respective means of x and y

2. Regression equation of Y on X

Y= a + b X

The regression coefficient of Y on is X denoted as byx or b2

byx or b2 = or

where

γ is correlation coefficient

= Standard deviation of x

= Standard deviation of y

μx and μy are the respective means of x and

Analysis of variance (ANOVA)

Analysis of variance is a type of significance test. This method was given by R. A. Fisher. It is also known as F test or Fisher test or ANOVA. It is used in the analysis of variance. ANOVA tests the homogeneity between several means i.e., when the means are more than two ANOVA is used as the test of significance. ANOVA is a collection of statistical models and their associated features in which the observed differences of variance are calculated. It is like t- test applied to more than 2 means. Doing multiple two sampled t-test results in an increased chance of committing type I error therefore, ANOVA is useful in comparing more than 2 means.

ANOVA is of two types

1. One-way analysis
2. Two-way analysis

One-way analysis

In this case the influence of any one factor is considered. For example, effect of use of one or more types of fertilizers on wheat crop. The first in analysis is to state the null hypothesis H0 which says that there is no significant difference between the means under study. Null hypothesis is hypothesis of no difference.

H0: μ1= μ2 = μ3 = …….. μk

k is the number of treatments

Treatments	Individual readings - - - r	Total	Treatment Mean
t_1		T_1	T_1 /r
t_2		T_2	T_2/r
t_3		T_3	T_3/r
t_k		T_k	T_k/r
N= k×r = total no. of observations		G= T1 + T2 + T3 +…. Tk	

Source	d.f.	SS	MSS	F ratio
Treatment or columns	k-1	SST		
Error	N-k	ESS = TSS – SST		
Total	N-1	TSS		

Where

d.f.= degree of freedom

SS = Sum of squares

SST = Sum of squares due to treatment

ESS = Error sum of squares

MSS = Mean sum of squares

MST = Mean sum of squares due to treatment

MSE = Error mean sum of squares

r = no. of observations in each treatment

G = grand total of all the observations

N = Total no. of observations = k×r

TSS = total sum of squares

F= F ratio or variance ratio

C. F. = correction factor

TSS = Raw sum of squares – C.F.

d.f.

This F ratio or variance ratio is called as Fcal (Fcalculated)

Two way analysis

If we want to test the significance difference between varities of crop and different fertilizers we use two way analysis. Error is reduced in two way analysis. The rows are called treatment and columns are called blocks.

Source	d.f.	SS	MSS	F ratio
Treatment or columns	k-1	SST		
Blocks or rows	r-1	SSB		
Error	(k-1) (r-1)	ESS = TSS – SST		
Total	kr-1	TSS		

If Fcal (Fcalculated) < Ftab(Ftabulated) then null hypothesis is accepted which means that there is no significant difference between the means under study.

If Fcal (Fcalculated) > Ftab(Ftabulated) then null hypothesis is rejected which means that there is significant difference between the means under study.

20.2 EXERCISE

1. Calculate the Karl Pearson correlation coefficient between x and y for the given data

x	43	54	59	68	76
y	105	98	84	63	50

Answer: r= 0.41

2. Find the lines of regression X on Y and Y on X for the data given:

X	3	5	6	6	9
Y	2	3	4	6	5

Answer: Y= 0.6X + 0.4, X= 1.2Y + 1.2

3. Four types of fertilizers are used for crops and following is the production in tons.

Fertilizer	Production in tons			
A	15	10	9	7
B	18	13	12	8
C	3	4	6	5
D	1	7	8	5

Perform one way ANOVA. (given F tab= 3.49)

Answer: Fcal = 6.34

21.3 REFERENCES AND SUGGESTED READINGS

http://mobile-education.weebly.com/uploads/1/0/9/3/10931547/rock_identification_key1.pdf

https://www.medellin.unal.edu.co/~rrodriguez/geologia/mex/mex2.htm

https://ocw.mit.edu/courses/earth-atmospheric-and-planetary-sciences/12-001-introduction-to-geology-fall-2013/labs-and-exercises/MIT12_001F13_Lab2_Instrctn.pdf

https://pdfs.semanticscholar.org/7e6f/bfc984a891b4f641e3d3dd4da966ab7d0a48.pdf?_ga=2.241971268.719530691.1586852508-660368517.1488384875