Practical Manual

Rainfed Agriculture & Watershed Management

APA-307 2(1+1)

For

B.Sc. (Agriculture) III-Year (6^{th} Semester)

2020

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Syllabus APA-307, 2(1+1): Studies on climate classification, studies on rainfall pattern in rainfed areas of the country and pattern of onset and withdrawal of monsoons. Studies on cropping pattern of different rainfed areas in the country and demarcation of rainfed areas on the map of India. Interpretation of meteorological data and scheduling of supplemental irrigation on the basis of evapotranspiration demand of crops. Critical analysis of rainfall and possible drought period in the country, effective rainfall and its calculation. Studies on cultural practices for mitigating moisture stress. Characterization and delineation of model watershed. Field demonstration on soil & moisture conservation measures. Field demonstration on construction of water harvesting structures. Visit to rainfed research station/watershed.

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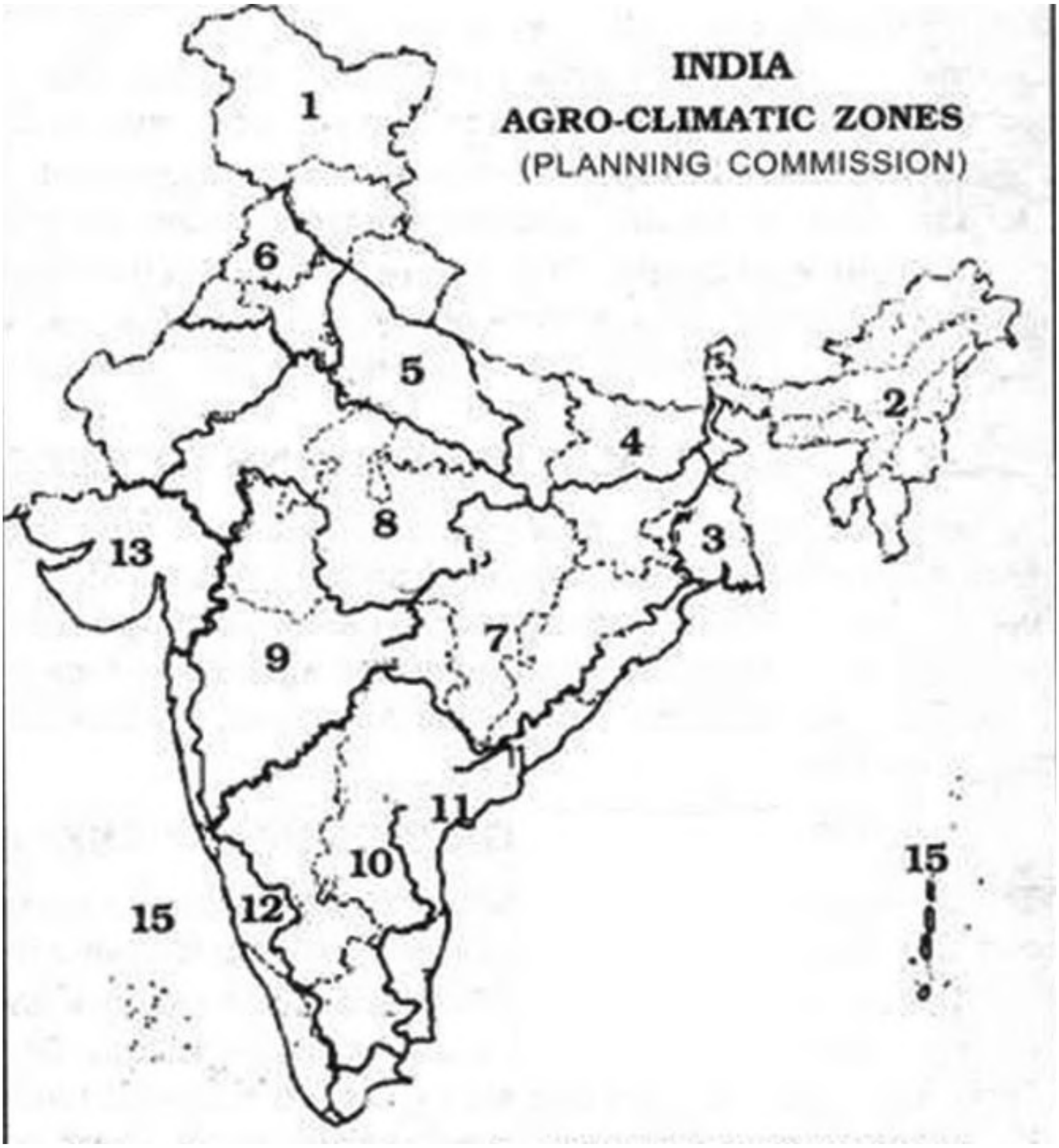
CONTENTS

Practical No. 1

Objective: To depict different Agro climatic zones of India on the given map

Exercise 1: Write the names of different agro-climatic zones (as per ICAR classification).

Procedure: Allocating different agro-climatic zones of India with different colors.



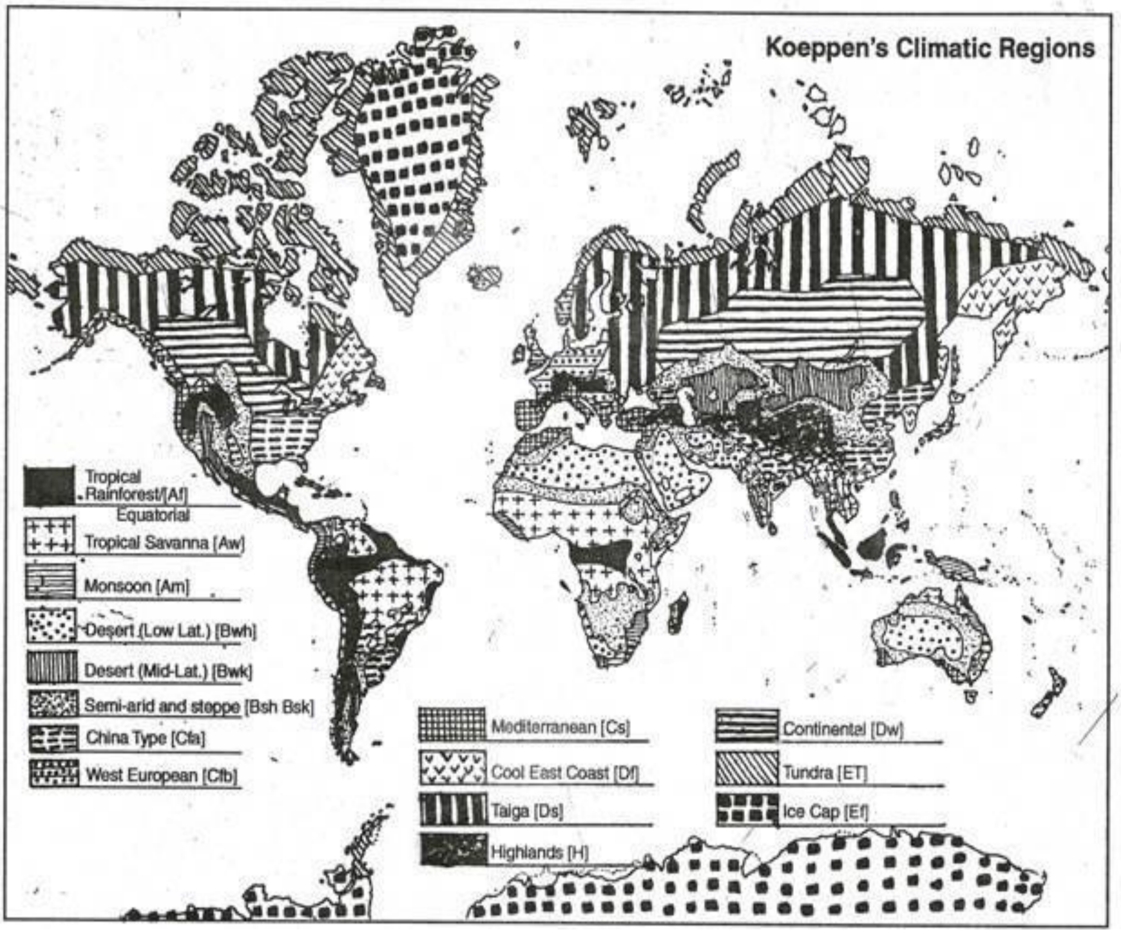
Depiction of different climatic zones of India on climate basis on map of India

Practical No. 2

Objective: To study climatic classification.

Exercise 1: Write about different climatic classifications.

Exercise 2: List the names of areas in the given map divided according to Koppen's classification of climate.



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Practical No. 3

Objective: To study rainfall pattern in rainfed areas of the country

Exercise: Mark in the map and write details different areas according to their rainfall pattern in the given map with rainfall distribution.

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Practical No. 4

Objective: To study onset and withdrawal of the monsoon

Exercise 1: Mention onset and withdrawal of monsoon in India with normal dates in the given map.

Exercise 2: Write about onset and withdrawal of monsoon.

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Practical No. 5

OBJECTIVE: To study cropping systems for dry land or rainfed areas

Exercise1: Write about different cropping systems suitable for rainfed area of India.

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Practical No. 6

OBJECTIVE: To study cropping systems for Bundelkhand region

Exercise 1: Write about different cropping systems suitable for rainfed area of Bundelkhand region (UP & MP).

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Practical No. 7

OBJECTIVE: To study rainfed area of India

Exercise 1: Demarcate rainfed area of INDIA with different colors on the map.
Materials required: Map of India, Pencil, colors.

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Practical No. 8

OBJECTIVE: To visit agrometeorological observatory

Exercise 1: Draw the layout plan of agrometeorological observatory you are visiting. Also list the names of instruments in observatory.

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Practical No. 9

OBJECTIVE: To interpret agrometeorological data

Exercise 1: Write about the instruments used for different parameters related to weather.

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Practical No. 10

OBJECTIVE: To study supplemental irrigation on the basis of evapotranspiration demand of crops

Exercise 1: Write about irrigation scheduling and supplemental irrigation.

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Exercise 2: How to schedule supplemental irrigation on the basis of evapotranspiration.

Practical No. 11

OBJECTIVE: To study critical analysis of rainfall and possible drought period in the country

Exercise 1: Analyse the rainfall data of the country.

Procedure: Collect the rainfall data from the Department of Agrometeorology of areas of India. Hence, depict drought period of areas in the region.

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Practical No. 12

OBJECTIVE: To study critical analysis of rainfall and possible drought period for Bundelkhand region.

Exercise 1: Analyse the rainfall data of the Bundelkhand region.

Procedure: Collect the rainfall data from the Department of Agrometeorology of areas of India. Hence, depict drought period of areas in the region.

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Practical No. 13

OBJECTIVE: To study effective rainfall.

Exercise 1: How to calculate effective rainfall?

Practical No. 14

OBJECTIVE: To study cultural practices for mitigating moisture stress

Exercise 1: What are the different cultural practices used for mitigating moisture stress.

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Practical No. 15

OBJECTIVE: To characterize and delineate Watersheds

Practical No. 16

OBJECTIVE: To demonstrate soil and moisture conservation practices

Exercise 1: What are the different methods to conserve soil and moisture?

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Practical No. 17

OBJECTIVE: To demonstrate construction of water harvesting structures

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Practical No. 18

OBJECTIVE: To visit rainfed research station/watershed

Exercise 1: Write down salient points you will see in research station during visit

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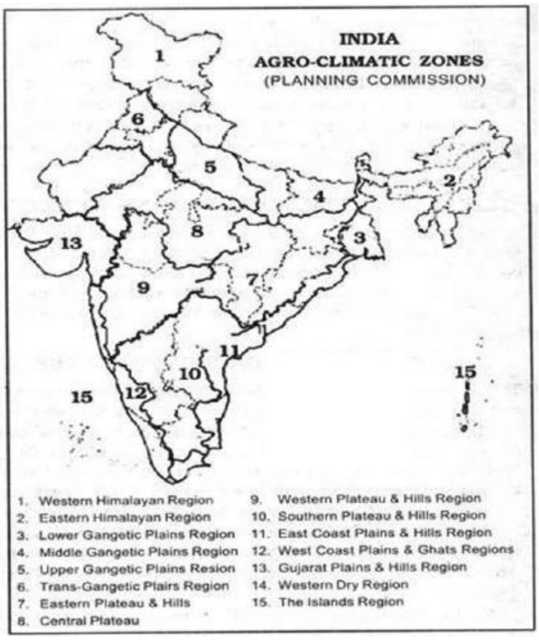
AGRO-CLIMATIC REGIONS

An agro-climatic zone is a land unit uniform in respect of climate and length of growing period (LGP) which is climatically suitable for a certain range of crops and cultivars (FAO, 1983). Classification by Planning Commission of India (1989) made an attempt to delineate the country into different agro climatic regions based on homogeneity in rainfall, temperature, topography, cropping and farming systems and water resources. India is divided into 15 agro-climatic regions.



Western Himalayan zone: This zone consists of three distinct sub-zones of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh hills. The region consists of skeletal soils of cold region, podsolic mountain meadow soils and hilly brown soils. Lands of the region have steep slopes in undulating terrain. Soils are generally silty loams and these are prone to erosion hazards.

Eastern Himalayan zone: Sikkim and Darjeeling hills, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Tripura, Mizoram, Assam and Jalpaiguri and Cooch behar districts of West Bengal fall under this region, with high rainfall and high forest cover. Shifting cultivation is practiced in nearly one-third of the cultivated area and this has caused denudation and degradation of soils with the resultant heavy runoff, massive soil erosion and floods in lower reaches and basins.

Lower Gangetic Plains zone: This zone consists of West Bengal-lower Gangetic plain region. The soils are mostly alluvial and are prone to floods.

Middle Gangetic Plains zone This zone consists of 12 districts of eastern Uttar Pradesh and 27 districts of Bihar plains. This zone has a geographical area of 16 million hectares and rainfall is high. About 39% of gross cropped area is irrigated and the cropping intensity is 142%.

Upper Gangetic Plains zone: This zone consists of 32 districts of Uttar Pradesh. Irrigation is through canals and tube wells. A good potential for exploitation of ground water exists.

Trans-Gangetic Plains zone This zone consists of Punjab, Haryana, Union territories of Delhi and Chandigarh and Sriganganagar district of Rajasthan. The major characteristics of this area are: highest net sown area, highest irrigated area, high cropping intensity and high groundwater utilization.

Eastern Plateau and Hills zone: This zone consists of eastern part of Madhya Pradesh, southern part of West Bengal and most of inland Orissa. The soils are shallow and medium in depth and the topography is undulating with a slope of 1-10%. Irrigation is through tanks and tube wells.

Central Plateau and Hills zone: This zone comprises of 46 districts of Madhya Pradesh, part of Uttar Pradesh and Rajasthan. The topography is highly variable nearly 1/3rd of the land is not available for cultivation. Irrigation and cropping intensity are low. 75% of the area is rainfed grown with low value cereal crops. There is an intensive need for alternate high value crops including horticultural crops.

Western Plateau and Hills zone: This zone comprises the major part of Maharashtra, parts of Madhya Pradesh and one district of Rajasthan. The average rainfall of the zone is 904 mm. The net sown area is 65% and forests occupy 11%. The irrigated area is only 12.4% with canals being the main source.

Southern Plateau and Hills zone: This zone comprises 35 districts of Andhra Pradesh, Karnataka and Tamil Nadu which are typically semi-arid zones. Dryland farming is adopted in 81% of the area and the cropping intensity is 111 percent.

East Coast Plains and Hills zone: This zone comprises of east coast of Tamil Nadu, Andhra Pradesh and Orissa. Soils are mainly alluvial and coastal sands. Irrigation is through canals and tanks.

West Coast Plains and Ghats zone: This zone comprises west coast of Tamil Nadu, Kerala, Karnataka, Maharashtra and Goa with a variety of crop patterns, rainfall and soil types.

Gujarat Plains and Hills zone: This zone consists of 19 districts of Gujarat. This zone is arid with low rainfall in most parts and only 32.5% of the area is irrigated largely through wells and tube wells.

Western Dry zone: This zone comprises nine districts of Rajasthan and is characterized by hot sandy desert, erratic rainfall, high evaporation, scanty vegetation. The ground water is deep and often brackish. Famine and drought are common features of the region.

Islands zone: This zone covers the island territories of Andaman and Nicobar and Lakshadweep which are typically equatorial with rainfall of 3000 mm spread over eight to nine months. It is largely a forest zone with undulated lands.

THE KOPPEN CLIMATE CLASSIFICATION SYSTEM

The Koppen climate classification system is a widely-utilized vegetation-based climate classification system that was created by the German botanist and climatologist Wladimir Koppen. The Koppen climate classification system is an attempt to come up with a formula to delineate climatic boundaries in correspondence with vegetation zones or biomes across the globe.

These biomes were in the process of being formulated and mapped for the first time during the time Koppen formulated his climate classification system in 1900. Koppen published a revised edition of his Koppen climate classification system in 1918, and afterwards continued to revise his system until he passed away in 1940 (A.J. Arnfield, 2017).

Throughout history, many attempts have been made in classifying the Earth's climates into climatic regions. The great Greek Philosopher Aristotle divided Earth into torrid, temperate and frigid zones, whose finer details are now redundant.

After this many attempts were made to classify the Earth's climatic regions, but none were as influential as the Koppen climate classification system. The Koppen climate classification system was introduced as a map in 1928 as one co-authored with Rudolph Geiger – a student of Koppen (M. Rosenberg, 2017). Since then, the Koppen climate classification system has been modified by various geographers.

The Koppen climate classification system, sometimes called the Koppen-Geiger climate classification system, is a terrestrial classification of climactic zones into five major types, which Koppen represented through the letters A, B, C, D, and E.

The present system of Koppen climate classification is based on the classification of climactic zones as based on both precipitation and temperature along with the corresponding vegetation. Temperature defines all the climactic zones except for B, as the determining factor for vegetation here is dryness, which can be categorized under precipitation.

Aridity however, is not determined only by precipitation and precipitation input in soil also works along with evaporation losses among plants. The five major climactic zones defined by Koppen as elucidated by Michael Pidwirmy, 2014 are –

A – Tropical Moist Climates (average temperature above 18^0C in all months)
B – Dry Climates (deficient precipitation for most of the year)
C – Moist Mid-Latitude Climates with Mild Winters
D – Moist Mid-Latitude Climates with Cold Winters
E – Polar Climates (extremely cold summers and winters).

CROPPING SYSTEMS FOR DRY LAND OR RAINFED AREAS

Cropping system is a significant component of farming system representing cropping patterns used on farm and their interaction with farm resources, other farm enterprises and available technology which determine their make-up. Cropping pattern means the proportion of area under various crops at a point of time in a unit area. It indicates the yearly sequence and spatial arrangement of crops and fallow in an area. Crop sequence and crop rotation are generally used synonymously. Crop rotation refers to recurrent succession of crops on the same piece of land either in a year or over a longer period of time. Component crops are so chosen that soil health is not impaired.

Types of cropping systems: Depending on the resources and technology available, different types of cropping systems are adopted on farms.

Mono-cropping: Mono-cropping or monoculture refers to growing of only one crop on a piece of land year after year. Mono-cropping in normal and below normal rainfall years.

Kharif crops – fallow

Fallow- *rabi* crops (on conserved moisture)

Multiple cropping: Growing two or more crops on the same piece of land in single calendar year is known as multiple cropping.

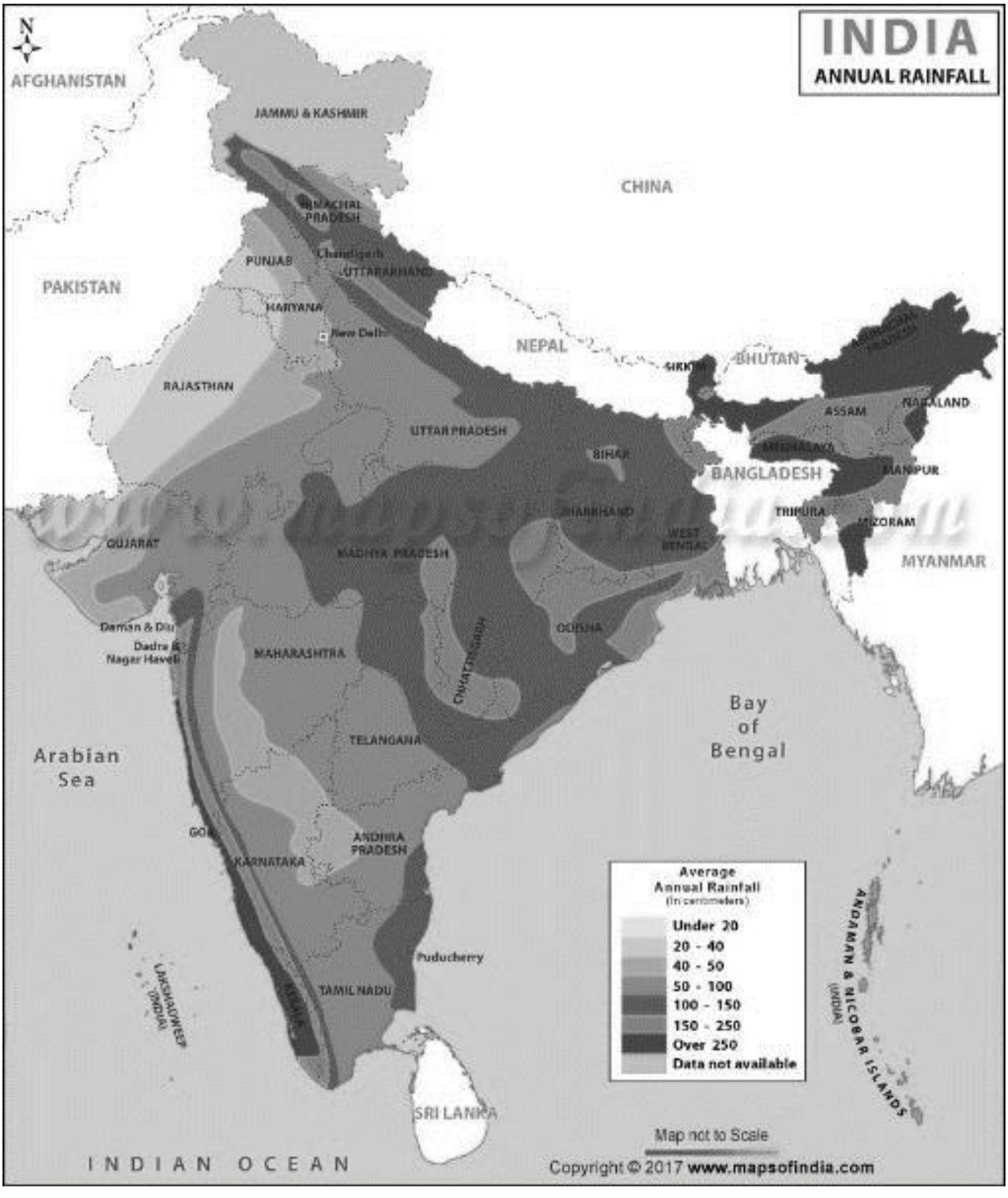
Double cropping in above normal rainfall years:

Pearl millet - chickpea
Black Gram- Pea/Gram
Jowar- Wheat
Bajra- Wheat
Green Gram - Lentil
Sesame- Pea
Sesame-Gram Mung bean - Mustard
Cowpea - mustard
Pearl millet + Cowpea - Mustard/Chickpea

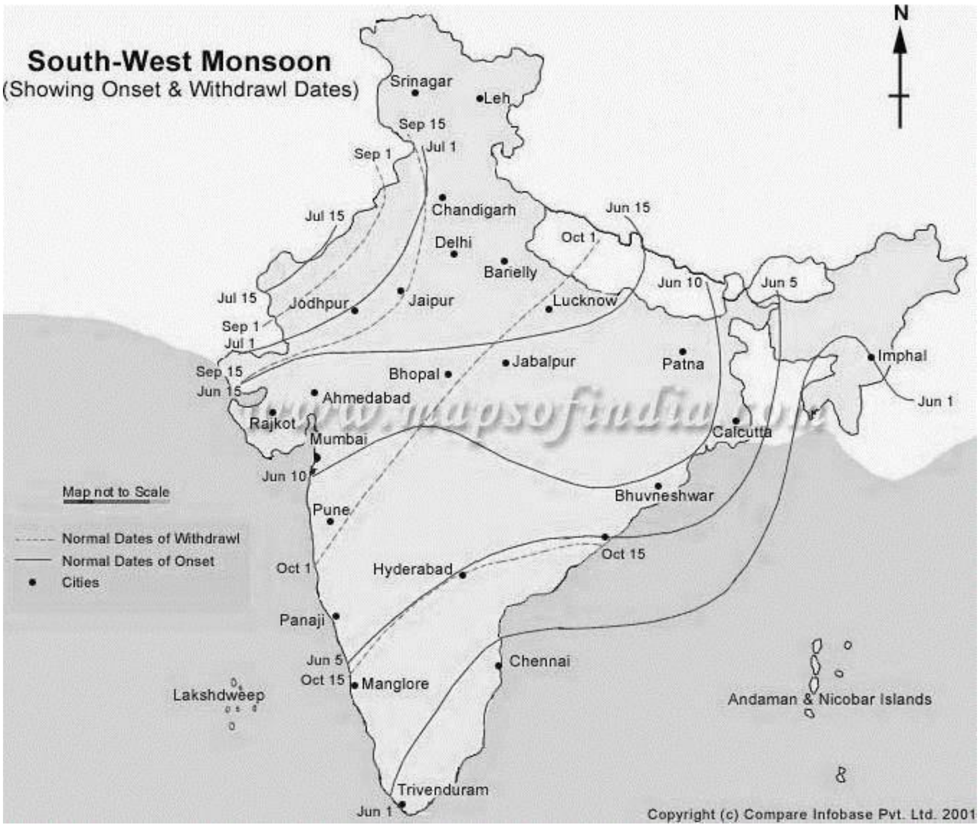
Intercropping

Pearl millet + Mung bean
Pearl millet + Black gram

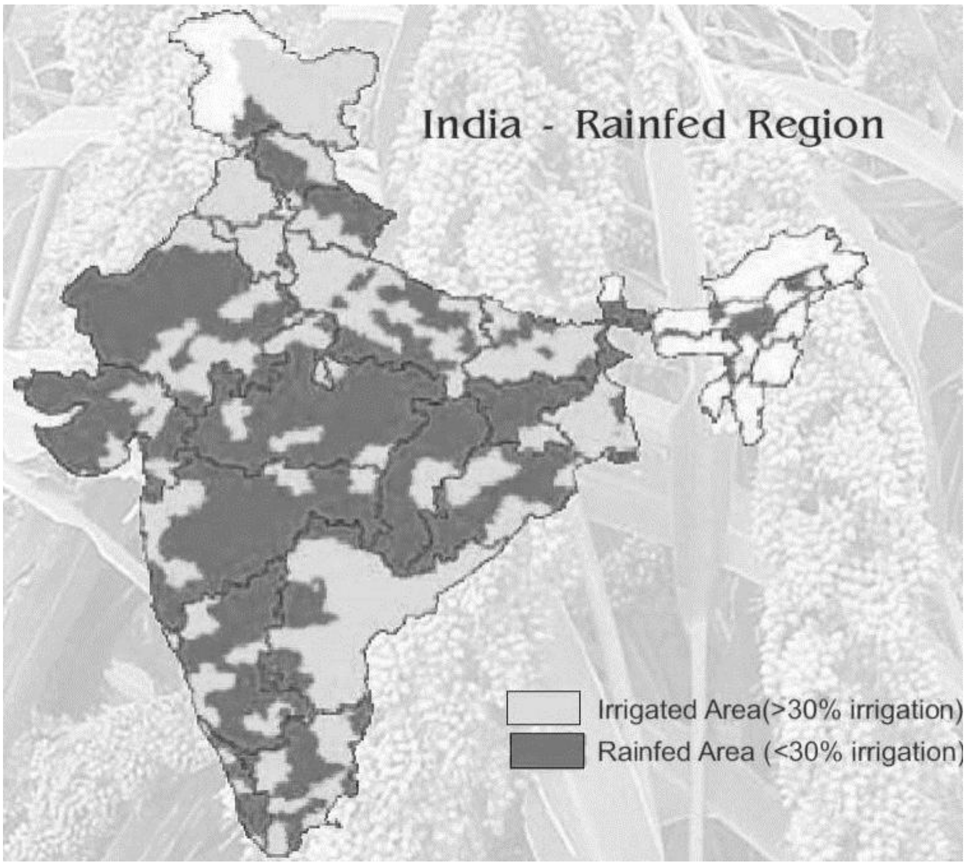
RAINFALL PATTERN IN INDIA



ONSET AND WITHDRAWAL OF THE MONSOON STUDIES



RAINFED AND IRRIGATED AREA IN INDIA



METEOROLOGICAL OBSERVATORY

Meteorological observatory is a place where all the necessary instruments are exposed for measuring weather phenomenon.
Four types of weather stations are recognized depending on the number of weather elements measured, the frequency of measurement and status of the observer. These four types of weather stations are as follows:

1. Synoptic stations
2. Agricultural stations
3. Climatological stations
4. Rainfall stations

The surface observatories are divided into six classes and each class is coded with letter as follows:

Class A observatories: These are provided with eye reading instruments and self-recording instruments. The observations are recorded after every hour round the clock.

Class B observatories: Most of these are furnished with eye-reading instruments and self-recording instruments. Regular observations are made at least twice in a day.

Class C observatories: These have the same instruments or equipment that are described in Class B observatories, but observatories are recorded only once in a day.

Class D, Class E and Class F observatories: These has a smaller number of instruments or equipment or are non-instrumental.

AGRO-METEOROLOGICAL OBSERVATORY

- Agro-meteorological observatory is a place where several instruments are installed and exposed to observe meteorological as well as biological parameters of crops.
- The observations are recorded at stipulated time. Agromet observatories are classified into three categories *viz*; i) Principal, ii) Ordinary and iii) Auxiliary types, depending upon the instruments (essential and optional) available in the observatory.
- The observations from Agro-meteorological observatories are recorded at stipulated time.
- These observatories are specifically located at the centre of the agricultural research farms of agricultural colleges and universities.

i) Principal Agro-meteorological observatory: The Central agromet observatory situated at Pune is one of such observatories. Principal agromet observatories undertake routine works, planned programmes and international collaborative projects.

a. Essential instruments

1. Maximum and minimum thermometers.
2. Wet and dry bulb thermometers.
3. Soil thermometers.
4. Grass minimum thermometer.
5. Rain gauge (ordinary and self-recording).
6. Wind vane and anemometer.
7. U.S.W.B. open pan evaporimeter.
8. Sunshine recorder.
9. Assmann psychrometer.
10. Dew gauge.
11. Thermo hygrograph.
12. Soil moisture equipment.
13. Solar radiation instruments.

b. Optional instruments

1. Lysimeter
2. Thermopile sensing elements for short and long wave net radiation.
3. Potentiometer.
4. Microvoltmeter.

ii) Ordinary agrometeorological observatory: These stations record meteorological as well as biological observations on routine basis.

a. Essential instruments

1. Maximum and minimum thermometers.
2. Wet and dry bulb thermometers.
3. Soil thermometers.
4. Grass minimum thermometer.
5. Rain gauge (ordinary).
6. USWB open pan evaporimeter.
7. Assmann Psychrometer.

b. Optional instruments

1. Sunshine recorder.
2. Dew gauge.
3. Self-recording rain gauge.
4. Thermo hygrograph.

iii) Auxiliary Agro-meteorological observatory: These types of observatories are equipped with few instruments and collect qualitative data on phenology and insects and diseases of economic importance to important crops of the region.

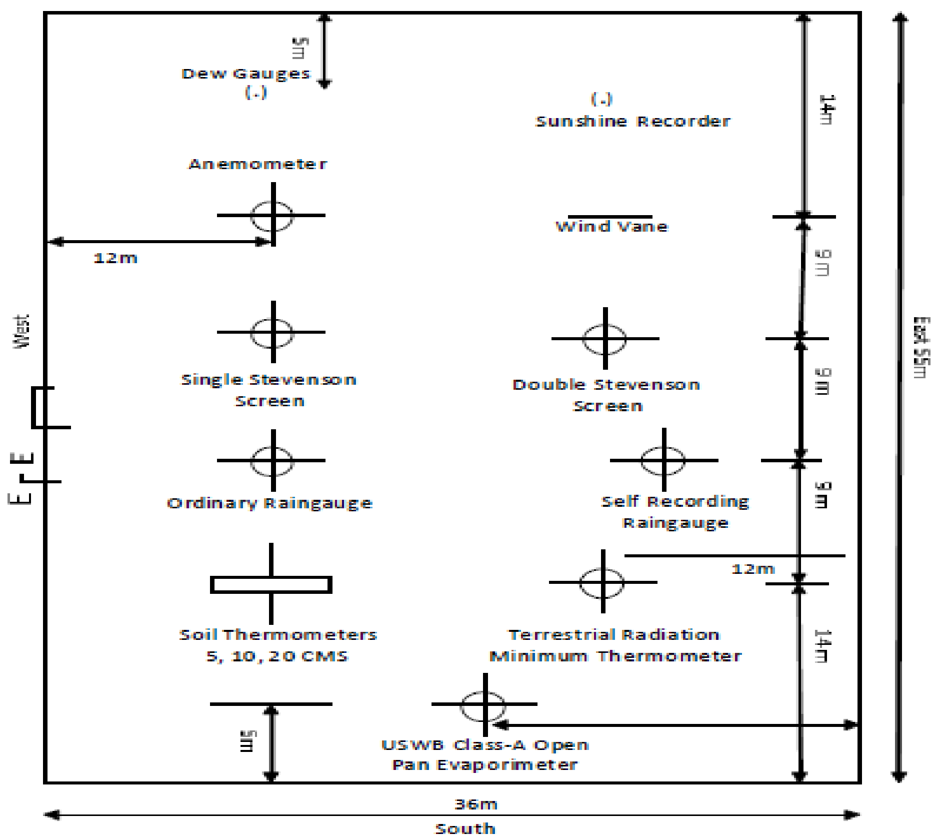
a. Essential instruments

1. Maximum and minimum thermometers.
2. Dry bulb and wet bulb thermometers.
3. Ordinary rain gauge.

b. Optional instruments

1. Wind vane and anemometer.
2. Dew gauge.

Layout of agromet observatory



Recommended layout

- The dimensions for an observatory are length of 55 m and width of 36 m and the longer side running South-North.
- The ground plan for an agromet observatory is given in Fig 1.
- The periphery should be fenced with barbed wires to prevent cattle trespass.
- There should be a gate at appropriate site.
- All tall instruments should be installed at the northern side of the observatory to avoid shade effect.

Time of observation

- The observations are recorded at 07.00 and 14.00 hours local mean time (LMT) all over India.
- However, rainfall and evaporation observations are taken at 08.30 hrs Indian Standard Time (IST) and 14.00 hrs LMT.
- The setting of automatic instruments like thermograph, hydrograph evaporigraph and barographs etc. are done at 08.30 hrs IST.

MEASURED ELEMENTS, UNITS IN GENERAL USE AND MEASURING INSTRUMENTS

S. No.	Element	Unit	Instrument(s)
1.	Temperature	Degree Celsius (°C)	Thermometer, Hygrograph
2.	Wind speed	kmph, mps, knots	Anemometer, Anemograph
3.	Wind direction	Degrees clockwise from north on the scale 00-36, where 36 is the wind from the north, 09 from the east and 00 refers calm.	Wind Vane, Anemograph
4.	Relative humidity	Per cent (%)	Dry and wet bulb thermometers, hygrograph
5.	Precipitation	millimeters (mm)	Rain gauge, dew gauge, Snow gauge
6.	Evaporation	millimeters (mm)	Evaporimeters
7.	Duration of sunshine hours	hours (h)	Sunshine recorder
8.	Cloud cover	Oktas (1/8 of the celestial dome)	Visual, observed in the observatory
9.	Atmospheric Pressure	Inches or milimeters	Barometer

IRRIGATION SCHEDULING

Once the crop water and irrigation requirements have been calculated, the next step is the preparation of field irrigation schedules. Three parameters have to be considered in preparing an irrigation schedule: I. The daily crop water requirements. II. The soil, particularly its total available moisture or water-holding capacity III. The effective root zone depth Plant response to irrigation is influenced by the physical condition, fertility and biological status of the soil. Soil condition, texture, structure, depth, organic matter, bulk density, salinity, sodicity, acidity, drainage, topography, fertility and chemical characteristics all affect the extent to which a plant root system penetrates into and uses available moisture and nutrients in the soil. Many of these factors influence the water movement in the soil, the water holding capacity of the soil, and the ability of the plants to use the water. The irrigation system used should match all or most of these conditions. The estimated values for available water-holding capacity and intake are shown as broad ranges in this Module. The values in local soil databases need to be continuously refined to fit the actual field conditions. In the field, the actual value may vary from site to site, season to season and even within the season. Within the season, it varies depending on the type of farm and tillage equipment, number of tillage operations, residue management, type of crop and water quality. Soils to be irrigated must also have adequate surface and subsurface drainage, especially in the case of surface irrigation. Internal drainage within the crop root zone can either be natural or from an installed subsurface drainage system.

SUPPLEMENTAL IRRIGATION

The addition of limited amounts of water to essentially rainfed crops to improve and stabilize yields when rainfall fails to provide sufficient moisture for normal plant growth - is an effective response to alleviating the adverse effects of soil moisture stress on the yield of rainfed crops during dry spells. Supplemental irrigation, especially during critical crop growth stages, can improve crop yield and water productivity.

1. Supplemental irrigation allows farmers to plant their crops early, increasing yields and preventing exposure to terminal heat and drought stress in hot areas, and frost in cold areas

2. The amount and timing of SI are optimally scheduled not to provide moisture stress free conditions throughout the growing season, but rather to ensure that a minimum amount of water is available during the critical stages of crop growth that would permit optimal yield.

3. Supplemental irrigation, especially during critical crop growth stages, can improve crop yield and water productivity.

EFFECTIVE RAINFALL

Weather forecasting and predicting the amount of rainfall that will occur in an area can be very tedious. It would involve meticulous observation of the atmospheric conditions and cloud formation along with the creation of models to simulate atmospheric conditions and cumulus cloud interaction which also leads to a high degree of complexity.

Finding the effective amount of rainfall involves analyzing the soil features, land features, groundwater quality and many more factors to find an accurate estimation. The amount of water used for irrigation is estimated without taking into consideration the effective amount of rainfall that will be experienced in a given area.

Thus, estimating the right amount of water that is to be supplied for irrigating the crops is of paramount importance. The method involves analyzing various geographical factors such as land topography, slope, channel features such as soil texture, structure and depth along with meteorological parameters such as Temperature, radiation, relative humidity, wind velocity to predict the amount of effective rainfall that will be received over specified geographic regions.

INFLUENCING FACTORS: The factors that influence effective rainfall and their significance are taken into consideration to determine the effective rainfall. The effect of several climatic factors on crop water needs.

PROPOSED METHODOLOGY: The system involves the use of a classifier to grasp the essence of its working. It is used to find the amount of water required for the irrigation of crops on a daily basis in the Bijapur and also to suggest a suitable irrigation system that can be implemented for high crop productivity.

Rainfall Characteristics

Potential Evapotranspiration

Other factors in determining effective rainfall

CULTURAL PRACTICES FOR MITIGATING MOISTURE STRESS

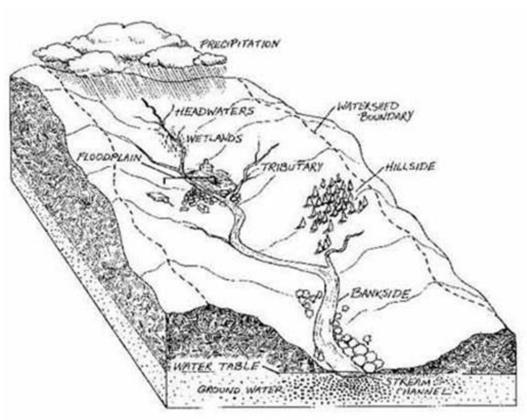
1. **Adjusting the plant population:** The plant population should be lesser in moisture stress conditions than under irrigated conditions. The rectangular type of planting pattern should always be followed under dryland conditions. Under dryland conditions whenever moisture stress occurs due to prolonged dry spells, under limited moisture supply the adjustment of plant population can be done by
   a) Increasing the inter row distance: By adjusting a greater number of plants within the row and increasing the distance between the rows reduces the competition during any part of the growing period of the crop. Hence it is more suitable for limited moisture supply conditions.
   b) Increasing the intra row distance: Here the distance between plants is increased by which plants grow luxuriantly

from the beginning. There will be competition for moisture during the reproductive period of the crop. Hence it is less advantageous as compared to above under limited moisture supply.

2. **Mid-season corrections:** The contingent management practices done in the standing crop to overcome the unfavorable soil moisture conditions due to prolonged dry spells are known as mid-season conditions.
    a) **Thinning:** This can be done by removing every alternate row or every third row which will save the crop from failure by reducing the competition
    b) **Spraying:** In crops like groundnut, castor, red gram, etc., during prolonged dry spells the crop can saved by spraying water at weekly intervals or 2 per cent urea at week to 10 days interval.
    c) **Ratooning:** In crops like sorghum and bajra, ratooning can practice as mid-season correction measure after break of dry spell.
        1. **Mulching:** It is a practice of spreading any covering material on soil surface to reduce evaporation losses. The mulches will prolong the moisture availability in the soil and save the crop during drought conditions.
        2. Maintaining a protective cover of vegetative residues (straw, stalks and stubbles) on the soil surface yields satisfactory results against soil erosion risk. Mulching helps in protecting soil surface against raindrop impact, decrease in flow velocity by imparting roughness, improved infiltration capacity, and enhances burrowing activity of earthworms (Eudrilus) have been widely reported by improving soil moisture storage in the root zone.
        3. **Weed control:** Weeds compete with crop for different growth resources ore seriously under moisture stress conditions. The water requirement of most of the weeds is more than the crop plants. Hence, they compete more for soil moisture. Therefore, the weed control especially during early stages of crop growth reduce the impact of dry spell by soil moisture conservation.
        4. **Water harvesting and lifesaving irrigation:** The collection of run-off water during peak periods of rainfall and storing in different structures is known as water harvesting. The stored water can be used for giving the lifesaving irrigation during prolonged dry spells.
        5. **Bed planting:** Growing of crops on top of the beds enhances the infiltration rate, protects crops from lodging due to better root growth and provides invisible strength to the crop against excess moisture conditions. Under runoff management situation, bed planting coupled with drip irrigation using harvested rainwater also serves the need of the farmers.
        6. **Soil fertility management:** Addition of organic manures/compost predominantly increases humus forming material to improve soil structure, water holding capacity, microbial population and its activity, base exchange capacity and resistance to soil erosion. Proper soil management, ensuring continued maintenance and building up of fertility at a high level is crucial for the profitable use of agricultural lands. In addition, retention or incorporation of residues into the soil is also possible through the application of organic manures. Besides these practices, adoption of good agronomic practices such as deep tillage once in every three years through chisel plough, selection of drought or excess moisture stress tolerant, lodging resistance varieties, application of balanced fertilizers (macro and micronutrients as per the plant needs) along with organic manures, summer ploughing etc. reduces excess soil moisture stress and low moisture stress.

DELINEATION OF WATERSHEDS

Imagine a watershed as an enormous bowl. As waterfalls onto the bowl's rim, it either flows down the inside of the bowl or down the outside of the bowl. The rim of the bowl or the watershed boundary is sometimes referred to as the ridgeline or watershed divide. This ridge line separates one watershed from another.

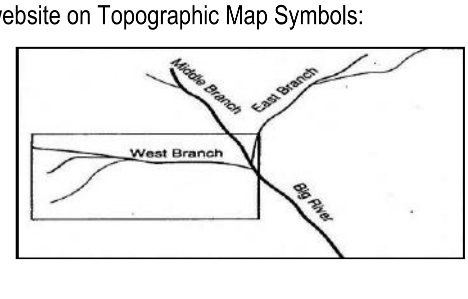


Topographic maps created by the United States Geological Survey (USGS 7.5-minute series) can help you to determine a watershed's boundaries.

Topographic maps have a scale of 1:24,000 (which means that one inch measured on the map represents 24,000 inches [2000'] on the ground). They also have contour lines that are usually shown in increments of ten or twenty feet. Contour lines represent lines of equal elevation, which typically is expressed in terms of feet above mean sea level. As you imagine water flowing downhill, imagine it crossing the contour lines perpendicularly.

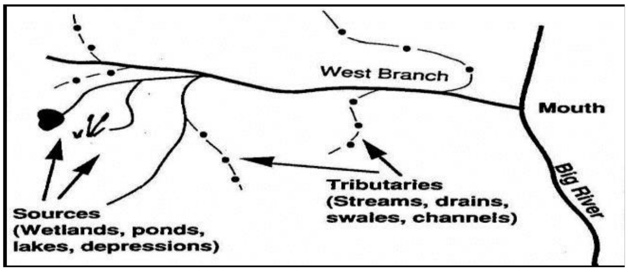
We describe basic topographic map concepts and symbols below, but more information can be found at the U. S. Geological Survey's website on Topographic Map Symbols:

How to delineate a watershed:

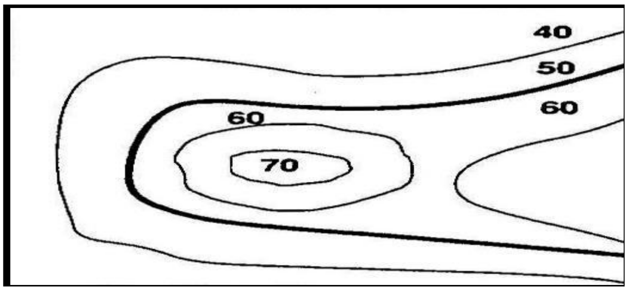


STEP 1: Use a topographic map(s) to locate the river, lake, stream, wetland, or other waterbodies of interest e.g., West Branch of Big River

STEP 2: Trace the watercourse from its source to its mouth, including the tributaries. This step determines the general beginning and ending boundaries e.g., West Branch sub-watershed.

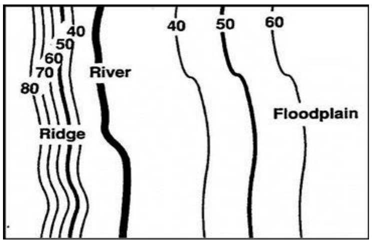


STEP 3: Examine the brown lines on the topographic map that are near the watercourse. These are referred to as contour lines. Contour lines connect all points of equal elevation above or below a known reference elevation e.g., Contour lines and an example point (X) at an elevation of 70 feet above sea.



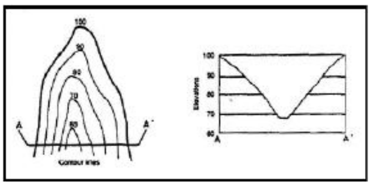
- The dark brown contour lines (thick lines) will have a number associated with them, indicating the elevation.
- The light brown contour lines (thin lines) are usually mapped at 10 (or 20) foot intervals, and the dark brown (thick) lines are usually mapped at 50 (or 100) foot intervals. Be sure to check the map's legend for information on these intervals.
- To determine the final elevation of your location, simply add or subtract the appropriate contour interval for every light brown (thin) line, or the appropriate interval for every dark brown (thick) line. Figure 3 shows a point (X) at an elevation of 70 feet above mean sea level.

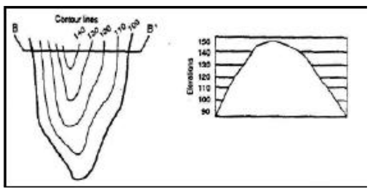
STEP 4: Contour lines spaced far apart indicate that the landscape is more level and gently sloping (i.e., they are flat areas). Contour lines spaced very close together indicate dramatic changes (rise or fall) in elevation over a short distance (i.e., they are steep areas) e.g., Floodplains and ridges.



STEP 5: Check the slope of the landscape by locating two adjacent contour lines and determine their respective elevations. The slope is calculated as the change in elevation, along a straight line, divided by the distance between the endpoints of that line.

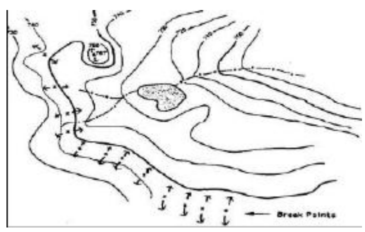
- A depressed area (valley, ravine, and swale) is represented by a series of contour lines "pointing" towards the highest elevation e.g., e.g., Valley.





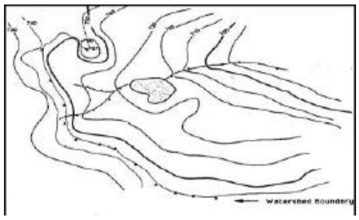
- A higher area (ridge, hill) is represented by a series of contour lines "pointing" towards the lowest elevation e.g., Ridge.

STEP 6: Determine the direction of drainage in the area of the water body by drawing arrows perpendicular to a series of contour lines that decrease in elevation.

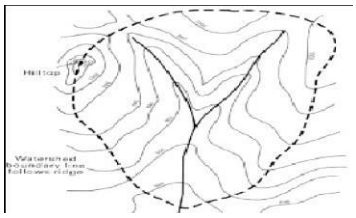


Storm water runoff seeks the path of least resistance as it travels down slope. The “path” is the shortest distance between contours, hence a perpendicular route e.g., Direction of drainage.

Mark the break points surrounding the water body. The “break points” are the highest elevations where half of the runoff would drain towards one body of water, and the other half would drain towards another body of water e.g., Watershed boundary.



STEP 8: IDENTIFY BREAK POINTS Connect the break points with a line following the highest elevations in the area. The completed line represents the boundary of the watershed e.g., Idealized Watershed Boundary.



STEP 9: Once you’ve outlined the watershed boundaries on your map, imagine a drop of rain falling on the surface of the map. Imagine the water flowing down the slopes as it crosses contour lines at right angles. Follow its path to the nearest stream that flows to the water body you are studying. Imagine this water drop starting at different points on the watershed boundaries to verify that the boundaries are correct.

STEP 10: Distribute copies of your watershed map to your group.

STEP 11: Watersheds sometimes have what are termed sub watersheds within them. Rivers, large streams, lake, and wetland watershed often have more than one sub watershed (usually smaller tributary watersheds) within them. Generally, the larger the water body you are examining, the more sub watersheds you will find. Your watershed map can be further divided into smaller sections or sub watersheds if it helps organize your study better.

STEP 12: Once the watershed and sub watershed (optional) boundaries have been delineated on the map, your team can verify them in the field, if necessary.

AGRONOMIC MEASURES OF SOIL AND MOISTURE CONSERVATION

Various method of moisture conservation in dryland areas are by storing in the root zone, by checking loss of water by evaporation and by water harvesting. Rainfall water can be conserved in following ways:

A) By storing more of rainfall in root zone.

1. Tillage,
2. Contour farming of bunding,
3. Vertical mulching,
4. Subsurface barrier,
5. Addition of pond sediments of organic matter
6. Addition of gypsum

B) By checking loss of water through evapotranspiration

1. Mulching,
2. Weed control
3. Use of anti-transpirants
4. Crop thinning

C) By water harvesting

1. **Water harvesting *in situ*.**
   i) Inter row water harvesting
   ii) Inter plot water harvesting
2. **Water harvesting for recycling:** Elaborate above agronomic measures in your own words hence also give at least 4 pictures of different watersheds in University farm area.

WATER HARVESTING STRUCTURES

A- Traditional Techniques

Dammed Ponds: Ponds are constructed by constructing a dam of soil across a flowing stream of water. These ponds may be very suitable for those areas where topography is rugged and slope is steep. In these structures, the collection of water is raised up to an optimum height. “Talab” is constructed by digging out soil in a leveled land. These ponds are fed by the surface runoff. The areas having heavy soils are suitable for these ponds because of low flowing rate of water into these ponds.

Cemented or Stoned: In the hilly areas due to steep slopes, it is not easy to construct big ponds. As a result, in these areas rainwater is carried out through “khuls” (mud irrigation water channel) to the agricultural fields and is stored then in small ponds. These ponds are made up of by cement and stones.

Construction of "Bauris" (springs): The "Bauris" (springs) nowadays are cemented storage structures which are used to collect water from natural sources and hence are rainfed. In this case, cemented storage structures are constructed across natural source of water and automatically considerable quantity of water gets accumulated therein.

B- Modern techniques

Run-off harvesting short-term storage: Contour bunds constructed along the contour lines trap the water and retain water behind the bunds, whose height and slope determine the water storage capacity. Crops or trees are grown within the bunds. Contour bunds range in the height from 0.3 to 1 m. The length of the bunds may range from 10 m to 100 m. This technique has been used in various countries as well as in this part of the country.

Semi-circular hoops: semicircular hoops consist of earth embankments which are constructed in the shape of a half-moon with the tips of the semi-circle on the contour. The water is collected within the hoop from the area just above it and impounded to a maximum depth defined by the height of the bund. The height of bunds ranges from 0.1 to 0.5 m and the radius may range from 5 m to 30 m.

Trapezoidal bunds: Trapezoidal bunds consist of earth embankments constructed in the shape of trapezoids. The tips of the bund are placed on the contour. Water is collected from the slopes above the bonded area and excess water overflows around the tips. The rows of bunds are intercepted to overflow from the above rows. The layout of trapezoidal bunds follows the same principles as those for semi–circular bunds, but they usually enclose a large bounded area. The height of the bunds ranged from 0.3 m to 0.6 m and their width across the tip ranges from 40 m to 160 m. These bunds are used extensively for irrigation of crops, grasses, shrubs or trees and enable inter-cropping within the large enclosed area.

Nala Bandhan (mini earthen check dams): The gullies and ravines originating from hills are transformed into the shape of "nala" (small stream) at the foothill and divide the agricultural and non-agricultural land into various segments. These "nalas" could conveniently be converted into series of mini water reservoirs with suitable structures such as earthen check dams. For constructing the check dams, trenches of size 1 m depth and 0.75 m width are excavated and filled with puddle clay. Above this foundation core, wall of the dam is prepared with puddle clay and the embankments over the core wall are prepared with locally available soil. Stone pitching on the upstream side is done to prevent damage of the dam. To drain out the excess rainwater side spillways at suitable height are provided with stone pitching. Between the earthen check dams for its strengthening, wall from loose boulders is constructed for minimizing the effect of run-off due to its velocity.

a. Off-contour bunds or graded bunds: Off-contour bunds consist of earthen or stone embankments which are built along 0.5-2.0% slopes. These contour bunds during high intensity of rain can be used for irrigation as well as safe drainage in case of access amount through the field. It provides opportunities of additional water for irrigation and safe disposal in case of excess water from the channels to the crop fields. The height of the bunds ranged from 0.3 m to 0.6 m. The bunds constructed below this range usually have a wing to help intercept water that over flows from the upper portion of the bunds.

b. **Rock catchment:** Exposed rock surfaces are used for the collection of water. The rainfall on the exposed rocks is drained through gravitational force to the lowest points, sometimes along low walls. Here, it is collected in a storage tank or reservoir of earth fill embankments; gravel stone fill embankments, stone masonry dams or concrete dams. The water from these reservoirs may be used for domestic, irrigation or sometimes for stock purposes.

c. Ground Catchment: The ground surface is used to collect water into storage tanks or reservoirs. The vegetation from ground is cleared, compacted and then reshaped to create a series of channels leading to the reservoir. So these grounds are compacted which sometimes are covered with gravel.

d. **Flood water harvesting–short term storage:** The wide valleys are re-shaped to form a series of broad terraces. The rainwater is collected within these terraces to form in these series of accumulating water flowing through stones, gabion or concrete weirs. The terraces are used to grow trees or crops. This water harvesting system is also useful in growing trees along the main roads.

e. Diversion of run-off: Diversion of water through flood is directly made into the fields. Water is diverted by a diversion dam which is sidetracked through channels to basins where the crops are irrigated with the help of flooding.

f. Check dams for aquifer recharge: Small rocks or concrete dams are built across the depressions to slow down the velocity of flow to enable a large amount of water to infiltrate into the alluvium under the channel bed. This added infiltration helps replenish the aquifers. Water is stored in the aquifers and utilized through wells. This system permits less evaporation losses than a surface reservoir and also has less problem of siltation.

g. Sub–surface dams: Sub-surface vertical barriers are constructed across the alluvium and down to bed rock. The water intercepts within the alluvium. This water flows along the surface and is collected in sub-surface reservoir created by the barriers. Evaporation losses are minimal. Expensive construction is avoided so as to become these adoptable at user levels. Barriers are constructed from clay stone masonry, concrete or steel sheet and pipes. Water is utilized by gravity flow or shallow wells or bore-holes. It is a common practice to construct sub–surface dams together with sand dams.

h. **Roof rain water harvesting:** Now-a-days the techniques of roof rain water harvesting have been evolved with a view to encouraging rainwater harvesting and its use to supplement irrigation and domestic uses. Under this scheme all the buildings at household level have to bring within the provisions of roof water harvesting and its storage. With this practice rainwater is collected from the rooftops and is stored in the dug wells and ponds for washing, drinking of livestock population and irrigation.