BUAT Publication ID: BUAT (PD) 07/ 2024

Practical Manual

Rainfed Agriculture and Watershed Management

(Course No. AAG 321)

Degree Programme: B.Sc. (Hons.) Agriculture
Credits: 2(1+1)

Prepared by

Dr. Aniket Hanumant Kalhapure
Dr. Arun Kumar
Dr. Dinesh Sah
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BANDA UNIVERSITY OF AGRICULTURE & TECHNOLOGY
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C E R T I F I C A T E

This is to certify that Mr./ Miss. ________________________________ ID No._________ has performed the necessary exercises in Practical Course No. AAG 321 (Rainfed Agriculture and Watershed Management) and completed records/ tasks in this practical manual for the requirements of B.Sc. Hons. (Agri.) for the academic year 20…..- 20……

Dr. Aniket Hanumant Kalhapure
Course Instructor &
Assistant Professor of Agronomy

Ex. No. 1 & 2

STUDIES ON CLIMATE CLASSIFICATION

Climate classification is necessary to know and simplify the climatic similarities and differences between geographic areas. It enhances the scientific understanding of climates.

Methods of climatic classification

a. **Empirical methods:** It make use of observed environmental data, such as temperature, humidity, and precipitation, or simple quantities derived from them (such as evaporation).
b. **Genetic methods:** It classify climate on the basis of its causal elements, the activity and characteristics of all factors (circulation systems, fronts, jet streams, solar radiation, topography etc.) that give rise to the spatial and temporal patterns of climatic data.

Hence, while empirical classifications are largely descriptive of climate, genetic methods are explanatory. However, for all practical applications empirical classifications are widely adopted.
In this exercise most widely accepted empirical climatic classification schemes have been discussed as below-

1. Koeppen's classification:

The most popular empirical classification is given by Wladimir Koeppen, in 1900 and several revised versions thereafter.

Koeppen's scheme used certain critical values of two parameters-

i. Temperatures of the warmest and the coldest months and
ii. Rainfall of the wettest and the driest months

His climatic divisions generally coincide with vegetational divisions. Koeppen (1936) divided the world climate into the following 5 principal groups.

A: Tropical rainy climate

Temperature of the coolest month does not exceed 18^{0}C. Five type of climates are described in this exercise.

Af - Tropical rainforest **(equatorial climate):** Warm Temperature throughout with mean value exceeding 27°C, abundant rainfall (annual average 250 cm), suitable for luxuriant vegetation. Prevails over Amazon basin, Zaire basin and south-east Asia.

Aw - Tropical savanna**:** Mean annual temperature 23°C, wet summers (due to convectional rainfall) and dry winter with annual rainfall 160 cm. Floods and droughts are common. Vegetation is tropical grassland or savanna with scattered deciduous trees. Prevails over Sudan, Veld plateau and the tropical grasslands of Australia.

Am - *Monsoon type*: Seasonal reversal of winds, associated with alternate periods of rainfall and drought with a short dry season.. This climate is experienced over the Pacific coast of Colombia, Guinea coast of west Africa, south-east Africa, south and south-east Asia and northern Australia.

As - Dry summer: A rare climatic type prevailing over some rainshadow areas along eastern coast of southern India in Tamil Nadu and Orissa that remain dry during summer monsoon and receive winter rainfall from retreating monsoons.

B: Dry climates:

Potential evaporation exceeds precipitation and constant water deficiency is experienced.

Bwh - *Desert* (Low Latitude) *Climate*: Sub-tropical high pressure region with mean annual temperature is 38°C and scanty and erratic rainfall. Vegetation varies with the soil type. This climate is experienced over southwest USA, north Africa (Sahara), west Asia, Thar desert, and central Australia.

Bwk - *Mid-Latitude Deserts*: These climatic conditions prevail over Takla Makan (China) and Gobi desert (Mongolia) and are similar to the low- latitude desert conditions.

Bsh and Bsk - *Semiarid and Steppe*: Mean annual temperature is around 21°C and rainfall a meager 30 cm. These regions are dry due to an interior location and absence of mountain barriers across the path of prevailing winds. These climatic conditions prevail over in the deep interiors of landmasses, such as Eurasia and North America.

C: Humid mesothermal/Warm temperate rainy

Mild winters; mean temperature of coldest month is below 18°C but above -3°C and that of the warmest month is above 10°C.

Cfa - *Humid subtropical or China type climate*: Hot and humid summer and mild winter with average annual temperature is 20°C and well distributed rainfall (100 cm). Hurricanes and typhoons are common. Prevails within 25° to 45° latitude on east coast in both hemispheres e.g., south-east USA, southern Brazil, Uruguay, Argentina, and south-eastern Africa, eastern coastal belt of Australia, eastern China and Japan.

Cfb - *Marine west European climate*: Characterised by on shore oceanic influences, short cool summers, mild winters with average annual temperature around 10°C and. and rainfall is 140 cm. Weather is variable and unpredictable. Prevails between 45° latitude and 65° latitude on west coast in both hemispheres e.g., Western Europe, narrow coastal belt in North and South America, -south-eastern Australia and New Zealand.

Cs - *Mediterranean climate*: Warm and dry summer (mean temperature 20°C- 27°C) due to sub-tropical high pressure conditions, mild winter (temperature 4°C to 10°C). with rainfall from low pressure cyclones (annual rainfall 40 cm- 60 cm). Prevails within 25° and 45° latitudes on west coasts in both hemispheres- over central California, central Chile, Mediterranean region, southern South Africa, southeastern and southwestern Australia.

D: Humid microthermal or Cold forest climates:

Severe winters, temperature of the coldest month is below -3°C and warmest month, above 10°C.

Df - *Cool east coast climate*: Hot and humid summer (mean temperature 25°C), influenced by tropical maritime air masses, cold winter (mean temperature -4°C to 0°C), . variable precipitation - convectional rainfall during summer and snowfall in winter. Prevails between 45° and 65° latitude on east coasts, over north-eastern USA, lower Danube plains, Korea, Japan, northern China.

Ds - *Taiga climate*: Short summer (temperature between- 10°C and 15°C), long and cold winters and low precipitation as influenced by continental polar air masses. Prevails over the belts from Alaska to Newfoundland and from Norway to Kamchetka peninsula sub-Arctic region. 'Taiga' actually refers to the softwood coniferous forest cover.

Dw - *Continental type climate*: Short and cool summer (temperatures 10° to 21°C), long and cold winters (temperatures below 0°C) and variable rainfall mostly during summers and snowfall during winter. Prevails in deep interiors of the continents between Taiga and the mid-latitude deserts over Poland and the Baltic states, Russian plains, northern states of USA and the southern states of Canada.

E: Polar climates:

Temperature of the warmest month is below 10°C. There is no warm season.

ET - *Tundra Climate*: Experienced over coastal fringes of the Arctic Ocean. Short, cool summer, long, cold winter and meager precipitation that limitTaiga vegetation.

Ef - *Ice Cap*: Areas permanently covered with snow. Average temperature of the warmest month is below 0°C. These conditions occur over the poles and the interiors of Greenland.

H: Highlands climate:

Prevails over the mountainous regions of Rockies, Andes, Alps and the Himalayas. Vegetational zoning from foothills upwards is similar to latitudinal change. High insolation, low temperature, low pressure, high precipitation and larger diurnal ranges at higher altitudes.

The significant aspect of Koeppen's classification scheme is that it uses measurable and visible physical, elements like temperature and precipitation and their combined interaction with vegetation as the basis of classification. Koeppen's scheme uses letter symbols to denote various characteristics, which is practical and convenient. However, it ignores other factors, such as cloudiness, wind, rainfall intensity, currents and, above all, the air masses which form the basis of modern climatology. It is also difficult to explain the existence of different vegetation types within the same climatic division and similar vegetation types in different climatic divisions.

2. Thornthwaite's rational classification

The main limitation of Koeppen's classification is the lack of rational basis for selecting temperature and precipitation values for different climatic zones. Thornthwaite's (1948) improved the same by introducing water balance concept in his classification scheme. He compared the potential evapotranspiration, PET (defined as the amount of water that could evaporate and transpire from a vegetated landscape without restrictions other than the atmospheric demand) with precipitation and computed 'moisture index' which considers the water surplus (s) and water deficit (d) which occur in different seasons in most places. Water surplus means seasonal addition to sub soil moisture that is being used by the crop at a reduced rate of transpiration during deficit period.

Thus, the climate of a place is defined on the basis of-

(i) Potential evapotranspiration i.e. the combines loss of moisture from vegetation surface as evaporation and transpiration
(ii) Seasonal variation of effective moisture
(iii) Average annual thermal efficiency.

According to Thornthwaite's classification scheme,

$$\text{Humidity Index} = I_h = \frac{100 \times s}{n}$$

$$\text{and Aridity Index} = I_a = \frac{100 \times d}{n}$$

Where;

s = Monthly water surplus calculated as the sum of the monthly differences between precipitation and potential evapotranspiration when precipitation is greater than evapotranspiration

d = Monthly water deficit calculated as sum of monthly values of potential evapotranspiration for those months when precipitation is less than evapotranspiration

n = Water need

Thornthwaite assumed that a surplus of 6 inch of water will counteract a deficit of 10 inch and thus gave higher weightage to humidity index. Thus, Moisture Index is given by-

$$Im = I_h - 0.6 \times I_a = \frac{100s - 60d}{n}$$

Table 1. Climate types and moisture index in Thornthwaite's classification

Symbol	Climate type	Moisture Index	Broad group
A	Per humid	100 and above	Moist climate
B4	Humid	80 to 100	
B3	Humid	60 to 80	
B2	Humid	40 to 60	
B1	Humid	20 to 40	
C2	Moist sub-humid	0 to 20	
C1	Dry sub-humid	- 20 to 0	Dry climate
D	Semi-arid	- 40 to - 20	
E	Arid	- 60 to - 40	

Thornthwaite has considered moisture index above zero as moist climate (A, B4, B3, B2, B1 and C2) and moisture index below zero as dry climate (C1, D and E). He has given subdivisions to express the extent of dry period under moist climate and extent of moist period under dry climate.

Table 2. Subdivisions of moist and dry climates in Thornthwaite's classification

Moist climate - description		Aridity Index	Dry climate - description		Humidity Index
R	Little or no water deficiency	0 - 10	D	Little or no water surplus	0 – 16.7
S1	Moderate summer water deficiency	10 – 20	S1	Moderate summer water surplus	16.7 – 33.3
W1	Moderate winter water deficiency	10 - 20	W1	Moderate winter water surplus	16.7 – 33.3
S2	Large summer water deficiency	≥ 20	S2	Large summer water surplus	≥ 33.3
W2	Large winter water deficiency	≥ 20	W2	Large winter water surplus	≥ 33.3

Thornthwaite considered potential evaporation as Thermal Efficiency (T-E index) and used it as a thermal limit in his climatic classification scheme.

Table 3. Thermal limits in climatic in Thornthwaite's classification

T-E Index	Thermal regime – climate Type*
0 – 14 cm	Frost (E)
14 – 28 cm	Tundra (D)
28- 56 cm	Microthermal (D, C1, C2)
56 – 98 cm	Mesothermal (C2, B1, B2, B3, B4)
Above 98 cm	Megathermal (B4, A1)

*Boundaries were taken in an arithmetic progression of T-E index with a common difference of 14 cm

Comparison of Koeppen's and Thornthwaite's Schemes

There are certain similarities as well as some distinct differences between the schemes of Koeppen and Thornthwaite. Both the schemes are based on empirical investigation. While Koeppen had considered vegetation to be a direct indicator of the totality of climate, Thornthwaite has given indirect recognition to the vegetational aspects through the concept of evapotranspiration which includes transfer of water from plants to atmosphere.

Both have used temperature and rainfall as basic atmospheric elements controlling climate. Koeppen considered the absolute values of critical climatic determinants, temperature and rainfall as recorded at different places. Thornthwaite. on the other hand, considered them through Thermal Efficiency and 'Precipitation Effectiveness', calculated by using evapotranspiration and moisture indices. Thornthwaite gave his scheme in 1931 and modified it thrice- in 1933, 1948 and 1955- each one being an improvement over the previous one. Thornthwaite's scheme is more widely used in applied climatology.

Climatic subdivisions of India

The vast expanse of India across the latitudes and longitudes, the presence of large mountain ranges, long rivers and wide range of soil types have led to diverse climatic conditions. Monsoon also plays a very significant role in modulating the seasonality. Considering the deep association of natural vegetation as well as agriculture and other economic activities and livelihood in general with the climate, it is important to characterize the climate at regional scale by adopting some rational basis for the identification and judicious exploration of potential natural resources. The climatic classification of India in the light of popularly used Koeppen's approach and Thornthwait's approach as well as the agroclimatic classification adopted by National Commission of Agriculture is being discussed here.

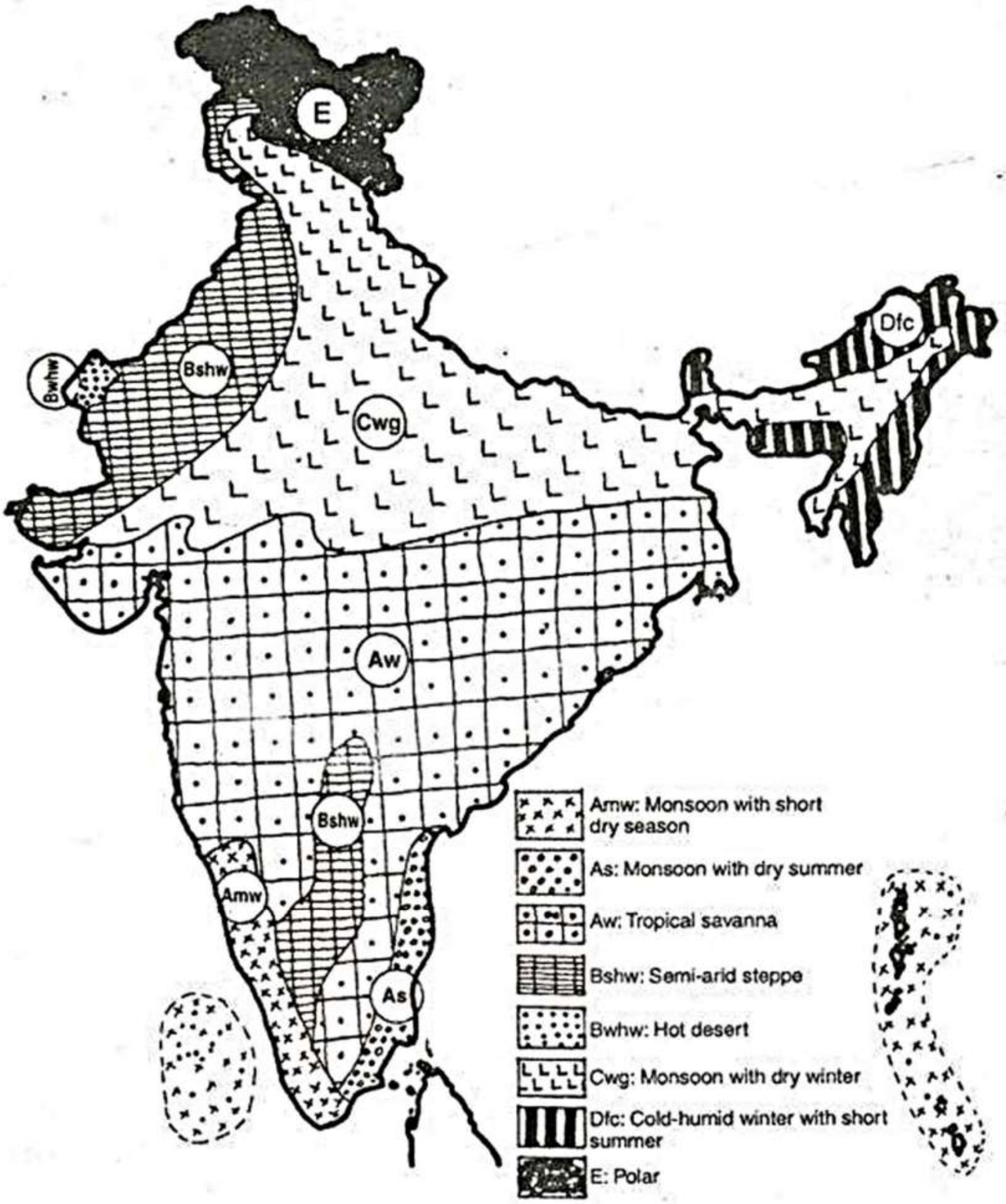
Climatic regions of India as per Koeppen's scheme

Based on Koeppen's method, India has eight climatic regions as described in figure 1. Those are-

1. Monsoon type with short dry season (Amw),
2. Monsoon type with dry season in summers (As),
3. Tropical savannah type (Aw),
4. Semiarid steppe climate (Bshw),
5. Hot desert type (Bwhw)
6. Monsoon type with dry winters (Cwg),
7. Cold humid winter type with short summers (Dfc)
8. Polar type (E)

As per the Koeppen's scheme the Amw type of climate prevails over the western coast of India, south of Goa. This type characterised by dry summers is experienced along the Coromandel Coast. The dry climate prevails over two parts in India. The interior peninsula, Rajasthan and parts of Haryana have Bshw type of climate, while the extreme western Rajasthan experiences Bwhw type of climate. Most of the peninsular plateau has tropical savannah type of climate (Aw). The plain of India falls under the warm temperate type of climate with dry winters (Cwg). The northeastern India falls under Dfc type of climate. Here, the winters are cold and humid, while the summers are short. Kashmir and the adjoining mountain ranges have a polar type of climate (E).

Figure 1: Climatic divisions of India as per Koppen's classification

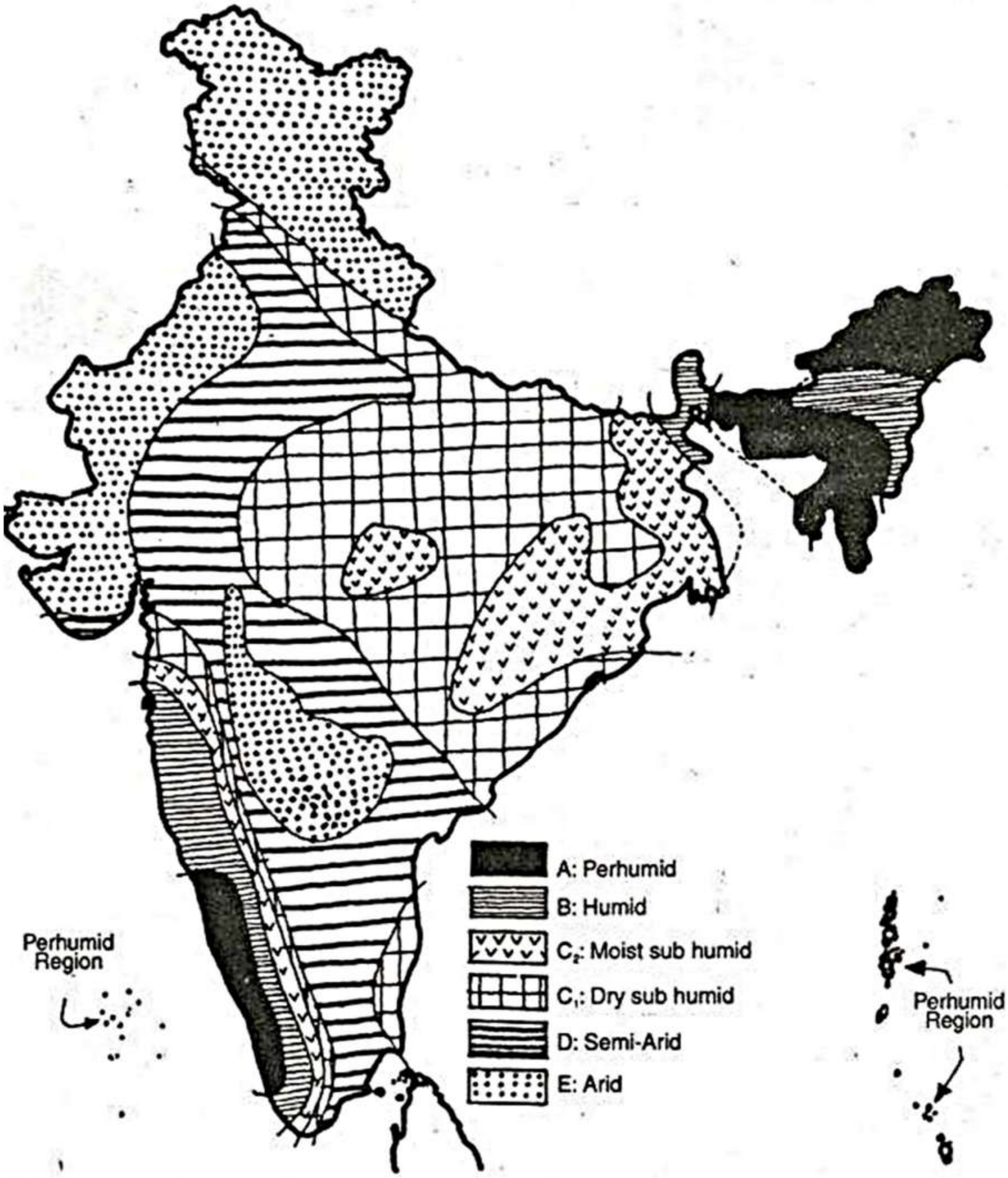


Climatic regions of India as per Thornthwaite's scheme

On the basis of Thornthwaite's method, the climate of India falls under six different groups. Those are-

1. Perhumid (A),
2. Humid (B4 to B1),
3. Moist sub-humid (C2),
4. Dry sub-humid (C1),
5. Semiarid (D) and
6. Arid (E)

Figure 2: Climatic divisions of India as per Thornthwaite's classification



According to the Thornthwaite's climatic classification scheme India have both moist and dry climates. Under moist climate the perhumid region (A) lies along the west coast of India, south of Goa and some parts of northeastern India. The humid climate (B) prevails all along the coast adjoining regions of west coast, northern part of West Bengal, and the neighbouring parts of northeastern India. The moist subhumid (C2) climate prevails along the Western Ghats and also over Orissa and West Bengal. The Ganga valley and northeastern parts of Central India have a dry subhumid type of climate (C1). The peninsular interior, western Madhya Pradesh, Haryana and Punjab have a semiarid type of climate (D). The regions of Saurashtra, Kuchchh and Rajasthan, on the other hand, experience an arid climate (E).

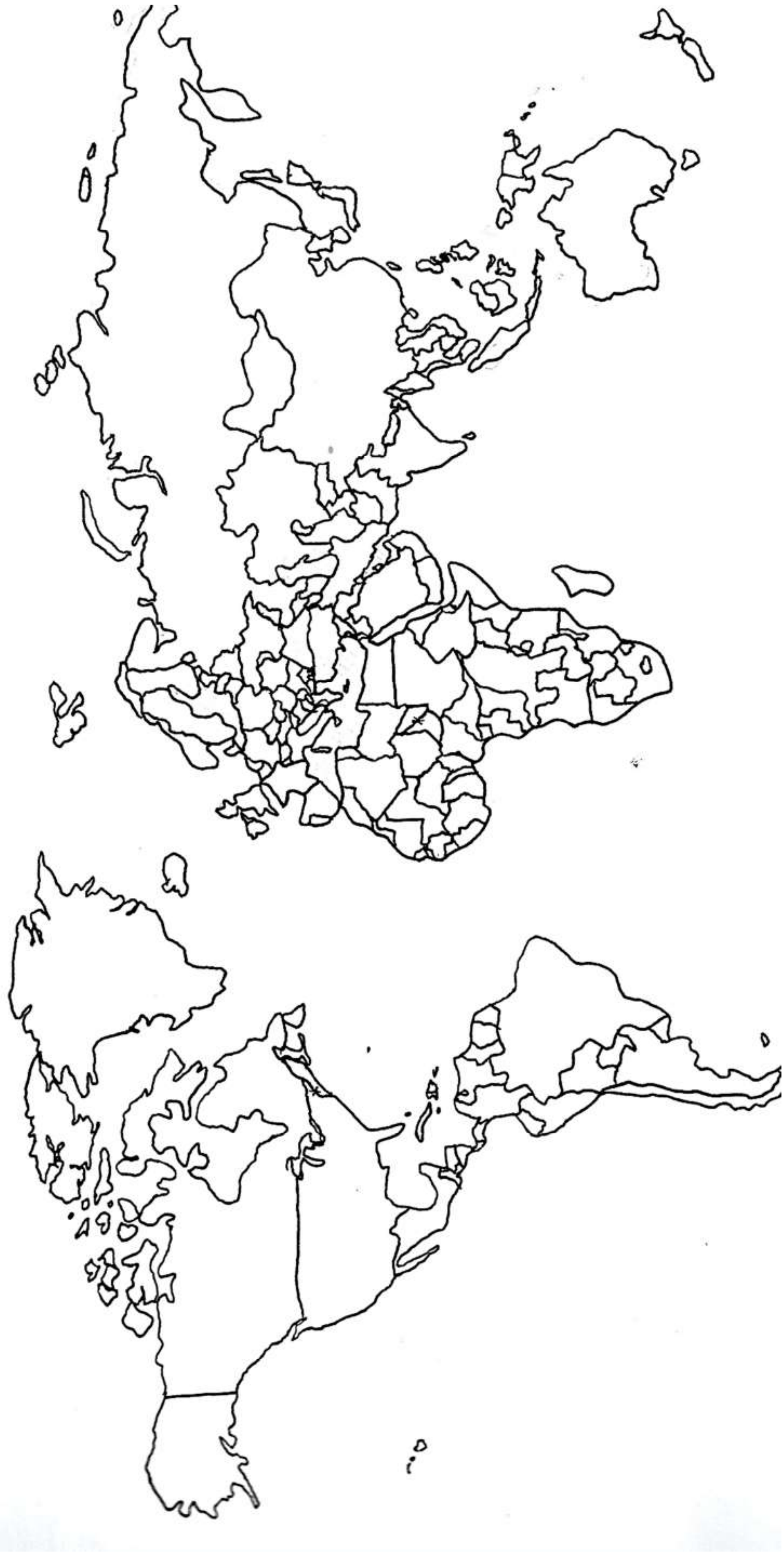
Task for Students

1. **With the help of figure 1 & 2 in this exercise and political map of India, list out the districts of India which is comes under arid and dry climatic condition.**

2. Demark Climatic divisions of India as per Koppen's classification on map

3. Demark Climatic divisions of India as per Thornthwaite's classification on map

4. Demark the climate zones in World map as per Koeppen's classification



5. Differentiate between Koeppen's and Thornthwaite's climate classification

Sr. No.	Koeppen's climate classification	Thornthwaite's climate classification

6. Summarize the types and features of Koppen's climate classification.

7. Summarize the types and features of Thornthwaite's climate classification.

3. Troll (1965)

- Based on thermal and hygric variables and number of humid months, climate is classified and said to be of agricultural use.
- Humid month is one having mean rainfall exceeding the mean potential evapotranspiration.
- ICRISAT classified the Semi-arid tropics (SAT areas) in India by adopting this classification.
- According to this classification, a climate which has 5 to 10 arid months (a month where precipitation is less than PET) or 2 to 7 humid months is called semi-arid tract (SAT), whereas humid climate will have 7 to 12 humid months and arid climate has less than 2 humid months.

Table 4: Climate classification of Troll

Humid months	Climate classification
12 to 9.5	Tropical rainforest
9.5 7.0	Humid savannah
7.0 4.5	Dry savannah
4.5 2.0	Thorn savannah
2.0 1.0	Semi desert
1.0 0.0	Desert

4. Papadakis (1961)

$$H = \frac{(P+W)}{E}$$

Where, P = Monthly precipitation, E = Monthly PET, W = Water stored from previous rainfall

Table 5: Climate classification of Papadakis

H Value	Climate
< 0.25	Arid
0.25 to 0.50	Dry
0.50 to 0.75	Intermediate
0.75 to 1.0	Intermediate humid
1.0 to 2.0	Humid
>2	wet

Moisture Index (H) based on precipitation, soil moisture storage and PET was developed.

Examples: Calculate moisture index (H) If P = 30mm, Evaporation of June = 60mm & water stored in root zone in May month = 5mm.

$$H = \frac{(P+W)}{E}$$

$$H = \frac{(30+5)}{60}$$

$$= 0.58$$

Therefore, Moisture index is 0.58mm so it comes under the climatic classification of intermediate climate.

Task for students:

1. **Calculate moisture index (H) If P = 20mm, Evaporation of July = 100mm & water stored in root zone in June = 5mm.**

2. **Calculate moisture index (H) If P = 40mm, Evaporation of October = 100mm & water stored in root zone in September = 15mm.4**

Ex. No. 3

STUDIES ON AGRO-CLIMATIC ZONES OF INDIA

Agro climatic zones:

An agro-climatic zone is a land unit in terms of major climate and growing period which is climatically suitable for certain ranges of crops and cultivars. Several attempts have been made in our country to classify the Agro-climatic zones. More often climate and ecology have been used as synonymous. Climate is the statistical collective of the weather conditions of specified area during a specified interval time, usually several decades. While Ecology is the relationship between organisms and their environment, including relationship with other organisms. Environment, therefore, is the total of all surroundings and natural conditions that affect the existence of living organism on earth, including air, water, soil, minerals, climate and organisms themselves. Thus climate and ecology are not interchangeable.

Agro-Climatic Zones of India:

The planning commission, as result of mid-term appraisal of planning targets of VII plan (1985-1990), divided the country into 15 broad agro-climatic zones based on physiographic and climate i.e. based on homogeneity in ago-characteristics such as rainfall, temperature, topography, cropping and farming systems and water resources. Since these zones were too broad to serve the purpose of planning, the project team set up for each agro-climatic zone was advised to divide each zone into sub zones under NARP. So these zones were further divided into 127 sub zones under National Agricultural Research Project (NARP) and Maharashtra is divided into 9 sub zones of NARP.

A) Himalayan Region:

1) **Western Himalayan Region:** This region comprises Jammu-Kashmir, Himachal Pradesh and U.P. Hills. Shallow skeletal soils of cold region, mountain meadow and hilly brown soils are predominant. Soils are generally silty loams and prone to erosion hazards. Lands or region have steep slopes in undulating terrain. The productivity of this region is lower than the all India level.
2) **Eastern Himalayan Region :** This comprises Sikkim and Darjeeling hills, Arunachal Pradesh, Megahalaya, Nagaland, Manipur, Tripura, Mizoram, Assam and Jalpaiguri and Coochbehar districts of West Bengal. The rainfall is high with thick forest cover. Shifting cultivation is practiced. High rainfall causes severe erosion and degradation of soil. This region is having a high potential for agriculture, forestry and horticulture.

B) Gangetic Plains:

3) **Lower Genetic Plains Region:** This zone consists of West Bengal lower Genetic plains region. Alluvial soils and are prone to floods. Rice cultivation is predominant.

4) **Middle Gangetic Plains Region:** This region comprises 12 districts of eastern U.P. and 27 districts of Bihar plains. About 61 % of area fall under rainfed farming and cropping intensity is 142 %. Rice productivity is the lowest in this zone.

5) **Upper Gangetic Plains Region:** The zone consists of 32 districts of North U.P. Problem soils is about 9 lakh ha. Irrigation by canal & tube wells with good ground water. Cropping intensity is 144 % productivity of Rice & Wheat is fairly high.

6) **Trans-Gangetic Plains Regions:** Punjab, Haryana, Union Territories of Delhi and Chandigarh and Sri Ganganagar in Rajasthan constitute this region. The major characteristics of this area are highest net sown area, irrigated area and cropping intensity and also high ground water utilization.

C) Plateau and Hills:

7) **Eastern plateau and Hill Regions:** The zone consists of eastern parts of M.P., southern part of West Bengal and most of inland Orissa. The soils are shallow to medium in depth. The topography is undulating with a slope of 1-10 %. Irrigation through tanks and tube wells.

8) **Central Plateau and Hill Regions:** This region comprises of MP (46 districts), U.P. and Rajasthan. About 75 % of the area comes under rainfed. Land topography is highly variable and about 30 % land is not available for cultivation.

9) **Western Plateau and Hill Region:** This zone consists of the major part of Maharashtra, parts of MP and one district in Rajasthan. Average Rainfall is 904 mm. Irrigated area is 12 % only, with canal being main source. Sorghum and cotton are the predominant crops in this area.

10) **Southern Plateau and Hill Region :** This is a typical semi-arid zone comprising 35 districts of Andhra Pradesh, Karnataka & T.N. about 80 % of the area falls under rainfed farming and hence cropping intensity is low (111 %).

D) Coastal Plain and Hills:

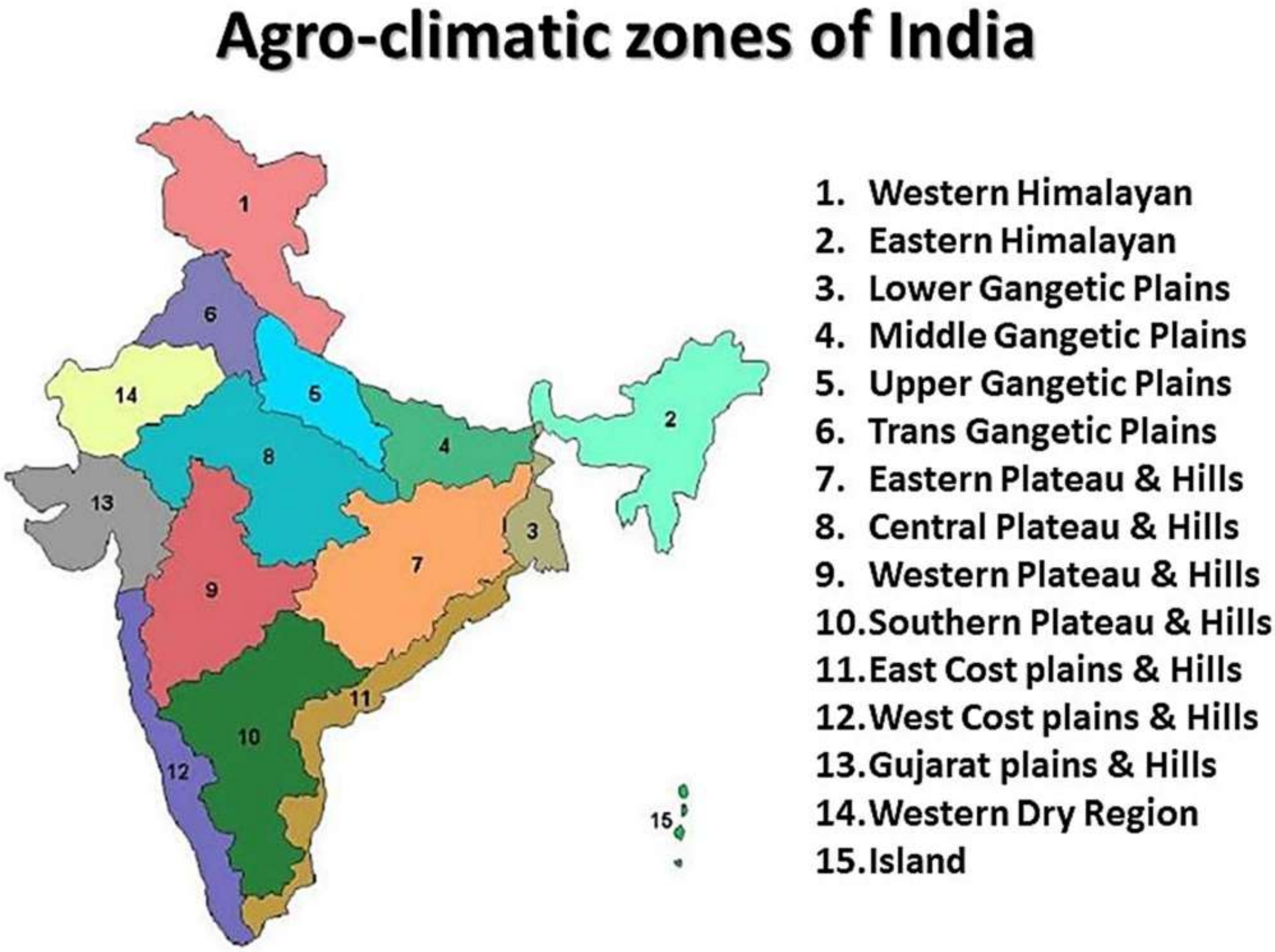
11) **East Coast Plains and Hill Region:** This zone comprises of east coast of T.N., Andhra Pradesh & Orissa. Soil is deep, loamy, coastal and deltaic alluvial type. Irrigation through canal and tanks. About 70 % land comes under rainfed farming.

12) **West Coast Plains and Hill Region:** The zone consists of west coast of T.N., Kerala, Karnataka, M.S. & Goa. Soils are shallow and medium, loamy, red and larteritic. Rice, tapioca, coconut and millets are the important crops.

13) **Gujarat Plains and Hill Region:** This zone comes under arid climate and covers 19 districts in Gujarat About 78 % of area falls under rainfed with low rainfall. This is an important zone of oil seed production.

14) **Western Dry Region:** This region is characterized by hot sandy desert spread in 9 districts of Rajasthan. Rainfall is erratic with high evaporative demand and vegetation is scanty. Drought and famine are very common features. Rainfall is only 400 mm. Temperature in winter is 0^{o}C while in summer it is 45^{o}C. The ground water is deep and often brackish.

15) Island Region: Island territories of Andaman, Nicobar and Lakshadweep come under this region. Soils are medium to deep, red loamy & sandy. Annual rainfall is 3000 mm spend over 8-9 months. It is largely a forest zone with undulating land.



Task for students: Briefly describe about the Agro-climatic zones of India

Salient Features of Agro-Climatic Zones of India (Planning Commission, 1989)

Zone No.	States represented and No. of districts	Representative soil	Rainfall (mm) and sub zones	Climate	Major crops
1.	J & K, H. P., U. P. (34)	Brown hill alluvial (recent) meadow skeletal	165-2000 (3)	Cold arid to humid	Wheat, maize, Rice Potato
2.	Assam, W. B., Manipur, Nagaland, Meghalaya (A. P.)	Alluvial, red loamy, red sandy, brown hill soil	1840-3528 (5)	Per humid to humid	Rice, Maize, Jute, Rape seed
3.	West Bengal (12)	Red and yellow deltaic alluvium, red loamy	1302-1607 (4)	Moist sub-humid to dry sub- humid	Rice, Jute, Wheat, Rape seed
4.	U. P. Bihar (38)	Alluvial	1211- 1607 (4)	- --do ---	- --do ---
5.	U. P. (32)	Alluvial	721-979 (3)	Moist sub-humid to dry sub- humid, arid	Rice, Wheat, Maize, Tur
6.	Punjab, Haryana, Delhi, Rajasthan (27)	Alluvial (recent) calcareous, desert	360-890 (3)	Extreme arid to dry sub-humid	Wheat, Gram, Jowar, Rice, Bajra
7	Maharashtra, M. P. Orissa, West Bengal (34)	Red sandy, Red and yellow	1271-1436(5)	Moist sub-humid to dry sub-humid	Rice, Wheat, Maize Ragi
8.	M. P., Rajasthan, U. P. (46)	Medium black, Deep black	450-1570 (14)	Semi-arid (drier half) to dry sub-humid	Wheat, Gram, Jawar Rice, Bajra
9.	Maharashtra, M. P., Rajasthan (34)	Medium black, Deep black, Red sandy, Red loamy	602- 1040 (4)	Semi arid	Jowar, Bajra, Cotton, Wheat
10	A. P. Karnataka, Tamilnadu (35)	Medium black, Deep black, Red sandy, Red loamy	577-1001 (6)	Semi arid	Jowar, Rice, Ragi, Groundnut
11.	Orissa, A. P., Tamilnadu, Pondicherry (25)	Deltaic alluvium, Red loamy	780-1287 (6)	Semi arid to dry sub-humid	Rice, Groundnut, Ragi, Jowar, Bajra
12.	Tamilnadu, Kerala, Goa, Karnataka, Maharashtra (27)	Coastal alluvium	2225-3640 (4)	Dry sub-humid, per humid	Rice, Ragi, Groundnut, tapioca
13.	Gujarat (22)	Laterite, Red loamy, Costal alluvium	340-1793 (7)	Arid to dry- sub- humid	Rice Groundnut, cotton, Bajra, Wheat
14.	Rajasthan (09)	Deep black, Coastal alluvium, Medium black	395	Arid to extremely arid	Bajra gram, Wheat, Rape seed
15.	A & N and Lakshadweep island	Desert, Gray, Brown undulating soils	1500-3086	Humid	Coconut, Forest and Grasses

Task for students: Demark Agro-climatic zones of India in the map below-

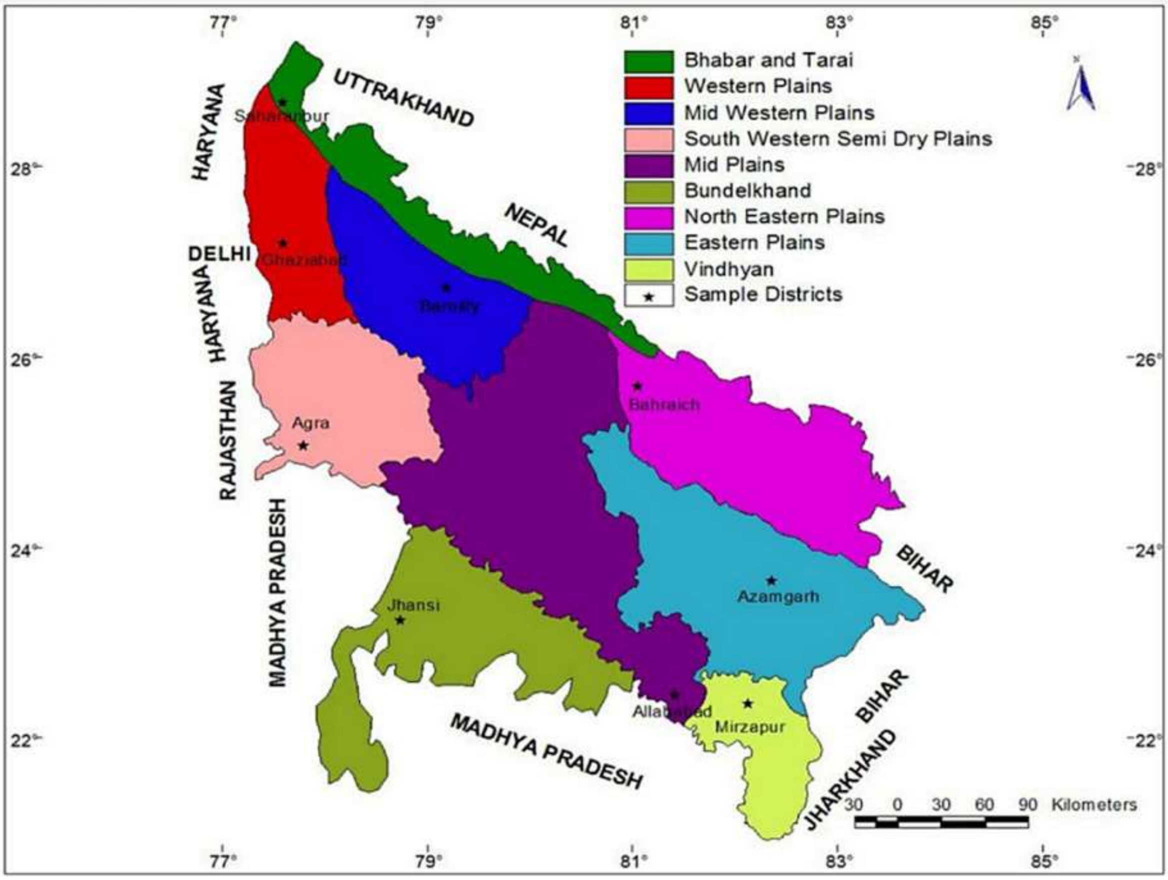
Ex. No. 4

STUDY OF AGRO CLIMATIC ZONES OF UTTAR PRADESH

On the basis of major climates suitable for a certain range of crops and cultivars, the Uttar Pradesh State is divided in 9 Agro-climatic zones as given below-

S.No.	Agroclimatic zone	Districts c overed	Total area (000 ha)	Mean Rainfall (mm)	Soil type
1	Bhabhar and Tarai zone	Saharanpur (58%), Muzaffarnagar (10%), Bijnor (79%), Moradabad (21%), Rampur (40%), Bareilly (19%), Pilibhit (75%), Shahjahanpur (6%), Kheri (39%), Bahraich (47%), Shrawasti (71%)	1847.3	1400	Alluvial, low to medium in phosphorus, medium to high in potassium and highly carbonized soils
2	Western Plain zone	Saharanpur (42%), Muzaffarnagar (90%), Meerut, Baghpat, Ghaziabad, Gautam Buddha Nagar, Bulandshahr	1637.4	795	Alluvial, pH value normal to sodic and low to medium carbonic soils
3	Mid western Plain zone	Bareilly (81%), Budaun, Pilibhit (25%), Moradabad (79%), J.P. Nagar, Rampur (60%), Bijnor (21%)	1697.1	1032	Almost alluvial normal to slight sodic and contains medium carbonic
4	South western semi arid zone	Agra, Firozabad, Aligarh, Hathras, Mathura, Mainpuri, Etah	2234.2	662	Alluvial and arawali.
5	Central plain zone	Shahjahanpur (94%), Kanpur Nagar, Kanpur Dehat, Etawah, Auraiya, Farrukhabad, Kannauj, Lucknow, Unnao, Rae Bareli, Hardoi, Kheri (61%), Sitapur, Fatehpur, Allahabad (58%) & Kaushambi	5647.3	863	Alluvial, pH value normal to sodic and low to medium carbonic soils

6	Bundelkhand zone	Lalitpur, Jhansi, Jalaun, Hamirpur, Mahoba, Banda and Chitrakoot	2961.0	867	Rakar, Parwa, Kabar and Maar
7	North eastern plain zone	Gorakhpur, Mahrajganj, Deoria, Kushinagar, Basti, Sant Kabir Nagar, Siddharthnagar, Gonda, Bahraich (63%), Balrampur and Shrawasti (29%)	2955.5	1240	Alluvial, calcareous
8	Eastern plain zone	Azamgarh, Mau, Ballia, Pratapgarh, Faizabad, Ambedkar Nagar, Barabanki, Sultanpur, Varanasi, Chandauli, Jaunpur, Ghazipur and Sant Ravidas Nagar (86%)	3808.7	803	Alluvial, sodic and Diarasoil
9	Vindhyan zone	Allahabad (42%), Sant Ravidas Nagar (14%), Mirzapur and Sonbhadra	1381.8	1134	Kali, Bhari red granules and alluvial soil in plane area



Task for students: Demark the Agro-climatic zones of UP on map given below

Exercise No. 5

STUDIES ON RAINFALL PATTERN IN RAINFED AREAS OF THE COUNTRY

Rainfall varies both in time and space. Rainfall varies from season to season and year to year. Generally higher the rainfall less is the coefficient of variation. In other words, without rainfall crop failures occurs mostly, in the regions of arid and semiarid regions.

Rainfall Seasons in India

a. **South-west Monsoon (June to September):** The South-west Monsoon is the most crucial season, governing agricultural production. While the monsoon's progression from the Kerala coast to Jammu and Kashmir is a regular phenomenon, annual variability is significant. The onset typically occurs on June 1st over Kerala and advances steadily across the country, with an exception in extreme parts of western Rajasthan where it arrives by mid-July. Most annual rainfall, except in Kashmir and parts of Tamil Nadu, is concentrated during this season. Monsoon withdrawal begins by September 1st from west Rajasthan, October 1st from western India up to west U.P., West M.P., and Gujarat, and concludes by mid-October across the country. The average monsoon rainfall for the whole country is about 850 + 90 mm, constituting 80-90% of the annual average of 1200 mm. Regional variations exist, with some areas like Orissa, east M.P., West Bengal, and the north-eastern states receiving more than 1000 mm, while peninsular India south of 15o N receives less than 500 mm. Western and north-western India receives around 650 mm, and extreme parts of Western Rajasthan receive less than 100 mm.
b. **Retracting South-west Monsoon (September 15-November):** Following the withdrawal of the South-west Monsoon in mid-October, the north-east monsoon strikes the Tamil Nadu coast in the 3rd week of October. Rainfall during this season decreases from the coast to interior places. Storms in the Bay of Bengal during October travel towards the north-east, while in November, they strike the southern Tamil Nadu coast with increased rainfall compared to October.
c. **North-east Monsoon / Western Disturbances (December - February):** This season is predominantly rainless over most parts of the country, except for north-west India and the south-eastern portion of the peninsula. Western disturbances cause rainfall in the former, supplementing moisture for rabi crops in north-west India. Cyclonic storms occasionally occur along the coastal districts south of Chennai, resulting in heavy rains. The north-east monsoon exhibits significant variability in onset and withdrawal.
d. **Summer Season (March - May):** In the early part of the season, western disturbances contribute to pre-monsoon showers in parts of North West India, progressing eastwards to the Gangetic plain and north-east India. In West Bengal and Assam, thunderstorms known as 'Norwesters' become more frequent, especially in

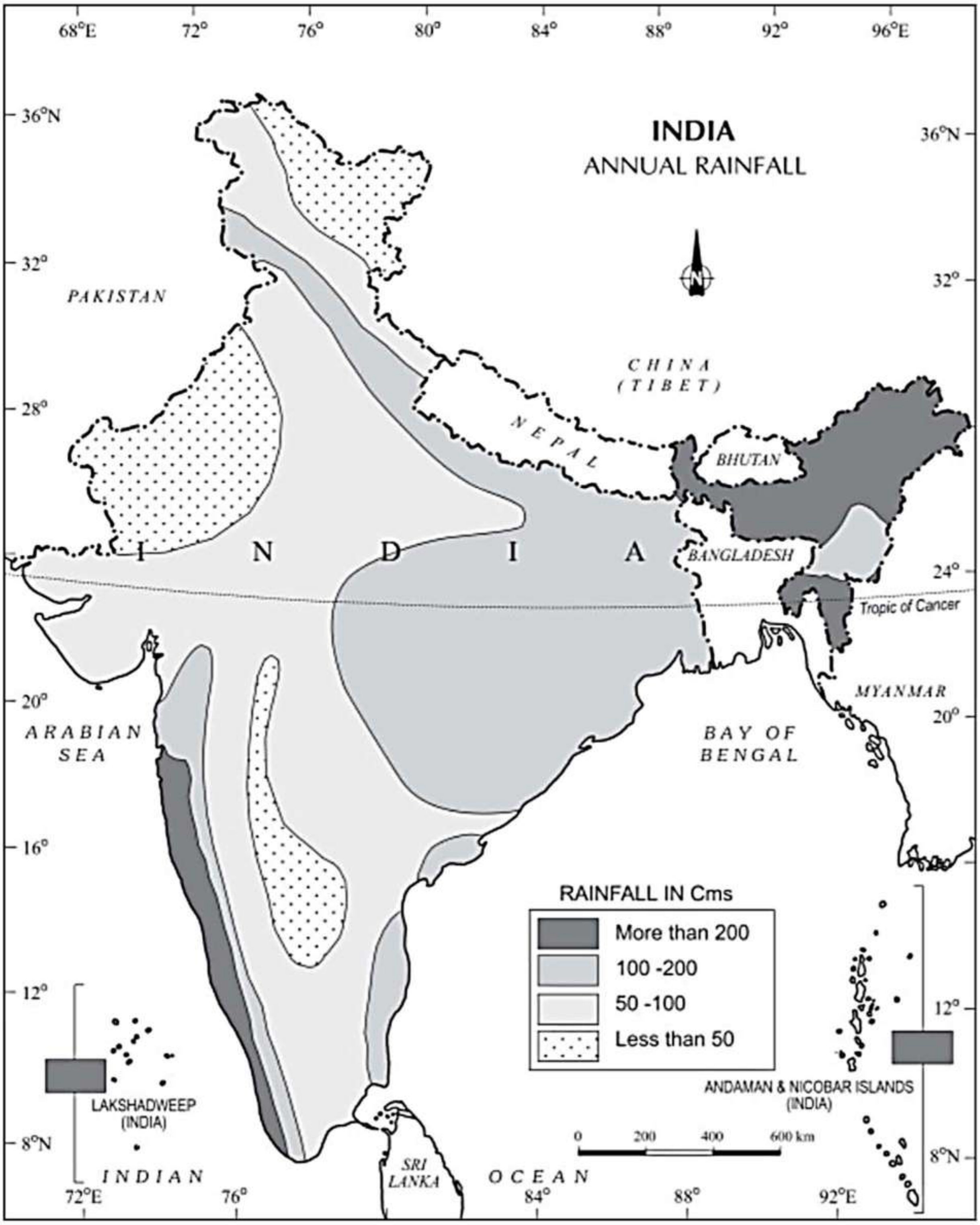
May, often accompanied by hailstorms. Conversely, in the North West parts of the country, dust storms replace thunderstorms.

The rainfall characterises needs to study for proper crop planning are as given below-

a. **Amount of rainfall:** It varies from year to year. Generally, yield levels are determined by amount of rainfall but, yields are not in direct proportion to amount of rainfall. Crop failure is more common.
b. **Intensity of rainfall:** In most parts of India more than 50% rain is received in 3-5 days. High intensity causes loss of water through runoff. It also causes soil erosion.
c. **Timing:** Rainfall is highly variable in time & space. Starting of rainy season is an important agro climate variable as rainfall is required initially for land preparation and sowing. It is also possible to estimate distribution of the start of the rains commencing on different dates using historical weather data.
d. **Duration of rainy season:** The length of growing season is limited by the duration of rainy season. It depends upon:
    - Starting of rainy season (Late onset)
    - Distribution of rainfall (Dryspell)
    - Ending of rainy season
    - Nature of soil with regard to water holding capacity
e. **Distribution of rainfall:** There is a large variation in commencement of rainy season from year to year. The monsoon is not continuous. Dry spells interspecific with wet spells sometimes to a period of even one month. There is a large year to year variation in the dates of cessation of S.W monsoon. There is a variation in the quantum of rainfall received.
f. **Onset of monsoon:** Long term data on onset of monsoon indicate that onset over Kerala state varies between 30 may to 2 June. It will extend all over India within 8-9 days. Delay in monsoon results in delay in sowing of crop. It also causes shifting of crops from commercial crops to pulse and other less remunerative crops
g. **Dry spells:** It is the number of continuous rainless days. It is a common feature of SW monsoon. A dry spell of round 10 days for sandy soils. 15 days for sandy loamy soils. 20 days or clay loams is critical. The no. of dry spells if more definitely affect the yield in dry lands.
h. **Early withdrawal of monsoon:** Post rainy season crops fail due to less available soil moisture in the soil. It ultimately leads to poor grain yield. Cycles of periods of low rainfall alternating with periods of higher rainfall as symbolized.
i. **Distribution of Annual Rainfall:**

Category	Region
Areas of High Rainfall (>200cm)	Areas along the west coast, on the Western Ghats, sub-Himalayan areas in the north east and the hills of Meghalaya, Brahmaputra valley and the adjoining hills
Areas of Medium	southern parts of Gujarat, east Tamil Nadu, north eastern Peninsula

Rainfall (100-200cm)	covering Odisha, Jharkhand, Bihar, eastern Madhya Pradesh, northern Ganga plain along the sub-Himalayas and the Cachar Valley and Manipur.
Areas of Low Rainfall (50-100cm)	Western Uttar Pradesh, Delhi, Haryana, Punjab, Jammu and Kashmir, eastern Rajasthan, Gujarat and Deccan Plateau
Areas of Inadequate Rainfall (<50cm)	Parts of the Peninsula, especially in Andhra Pradesh, Karnataka and Maharashtra, Ladakh and most of western Rajasthan



Task for students: With the help of above Image, demark the area with average annual rainfall less than 1000 mm on India's map given below-

Ex. No. 6

PATTERN OF ONSET AND WITHDRAWAL OF MONSOONS IN INDIA

The climate of India is profoundly shaped by the monsoon winds, a seasonal reversal of wind systems that brings vital rainfall to the region. The onset and withdrawal patterns of the monsoon play a crucial role in determining the agricultural and climatic conditions across the country. This exercise delves into the various factors influencing the monsoon, the mechanism of its onset and withdrawal, and the distribution of rainfall in different regions.

Factors Influencing Monsoons

1. Differential Heating and Cooling: The differential heating and cooling of land and water create low pressure over the Indian landmass and high pressure over the surrounding seas.
2. Position of Inter Tropical Convergence Zone (ITCZ): The shift of the ITCZ over the Ganga plain during summer, known as the monsoon trough, influences the monsoon.
3. High-Pressure Area in the Indian Ocean: The presence of a high-pressure area east of Madagascar in the Indian Ocean affects the monsoon's intensity and position.
4. Tibetan Plateau: The intense heating of the Tibetan plateau during summer leads to low pressure at high altitudes, contributing to the monsoon.
5. Jet Streams: The movement of the westerly jet stream north of the Himalayas and the presence of the tropical easterly jet stream over the Indian peninsula during summer impact the monsoon.
6. Southern Oscillation (SO) and El Nino: Changes in pressure conditions over the southern oceans, known as Southern Oscillation (SO), and the periodic El Nino phenomenon also influence the monsoons.

Onset of the Monsoon

Burst of the Monsoon: The monsoon, a dynamic and pulsating climatic phenomenon, graces the Indian subcontinent for about 100-120 days from early June to mid-September. The initiation of this annual meteorological event is characterized by a sudden and significant surge in rainfall, famously termed the 'burst' of the monsoon. This distinctive increase sets apart the onset from pre-monsoon showers, marking the beginning of a transformative period for the region.

Arrival in Different Regions: The monsoon commences its journey at the southern tip of the Indian peninsula, making its presence felt by the first week of June. It then divides into two primary branches, each embarking on a distinct trajectory:

i. **Arabian Sea Branch:** Advancing with notable speed, the Arabian Sea branch reaches the bustling city of Mumbai approximately ten days later, around the 10th of June. This swift progression underscores the urgency and vigor with which the monsoon winds make their way across the Arabian Sea.

ii. **Bay of Bengal Branch:** Simultaneously, the Bay of Bengal branch sweeps across the eastern coast, reaching Assam within the first week of June. The presence of lofty mountains along this route causes a deflection of monsoon winds towards the west, influencing the weather patterns over the Ganga plains.

Progression Over India: By mid-June, the Arabian Sea branch advances towards the western regions of Saurashtra-Kuchchh, while the Bay of Bengal branch moves towards the central part of the country. The culmination of their journey occurs over the northwestern part of the Ganga plains, where the two branches seamlessly merge. This merging marks a pivotal moment in the monsoon's progression, setting the stage for the widespread coverage of the subcontinent.

Delhi, the heart of the country, typically receives the much-awaited monsoon showers from the Bay of Bengal branch by the end of June. As July unfolds, the monsoon extends its reach to encompass western Uttar Pradesh, Punjab, Haryana, and eastern Rajasthan. By mid-July, the monsoon blankets Himachal Pradesh and spans the entirety of the country, completing its triumphant journey.

Advancing Monsoon (The Rainy Season)

Mechanism of Advancement: The transformational onset of the monsoon is closely tied to the intensification of low-pressure conditions over the northern plains by early June. This atmospheric change acts as a magnet, drawing southeast trade winds originating from the warm subtropical areas of the southern oceans. These winds, entering the Indian peninsula as the south-west monsoon, bring with them a wealth of moisture. The entire country witnesses the coverage of these strong monsoon winds in about a month.

Impact on Weather: The south-west monsoon, once established, ushers in a total metamorphosis in weather patterns. The windward side of the Western Ghats experiences heavy rainfall, exceeding 250 cm, while the Deccan Plateau and parts of Madhya Pradesh receive some rain despite being in the rain shadow area. The north-eastern part of the country, particularly Mawsynram in the southern ranges of the Khasi Hills, receives the highest average rainfall globally.

Conversely, regions such as Rajasthan and parts of Gujarat receive scanty rainfall, creating a distinct spatial variation in precipitation. The phenomenon of 'breaks' in monsoon, characterized by alternating wet and dry spells, adds an element of unpredictability to the seasonal rainfall. These breaks are intricately linked to the movement of the monsoon trough, which influences the spatial distribution of rainfall.

Retreating Monsoon (The Transition Season)

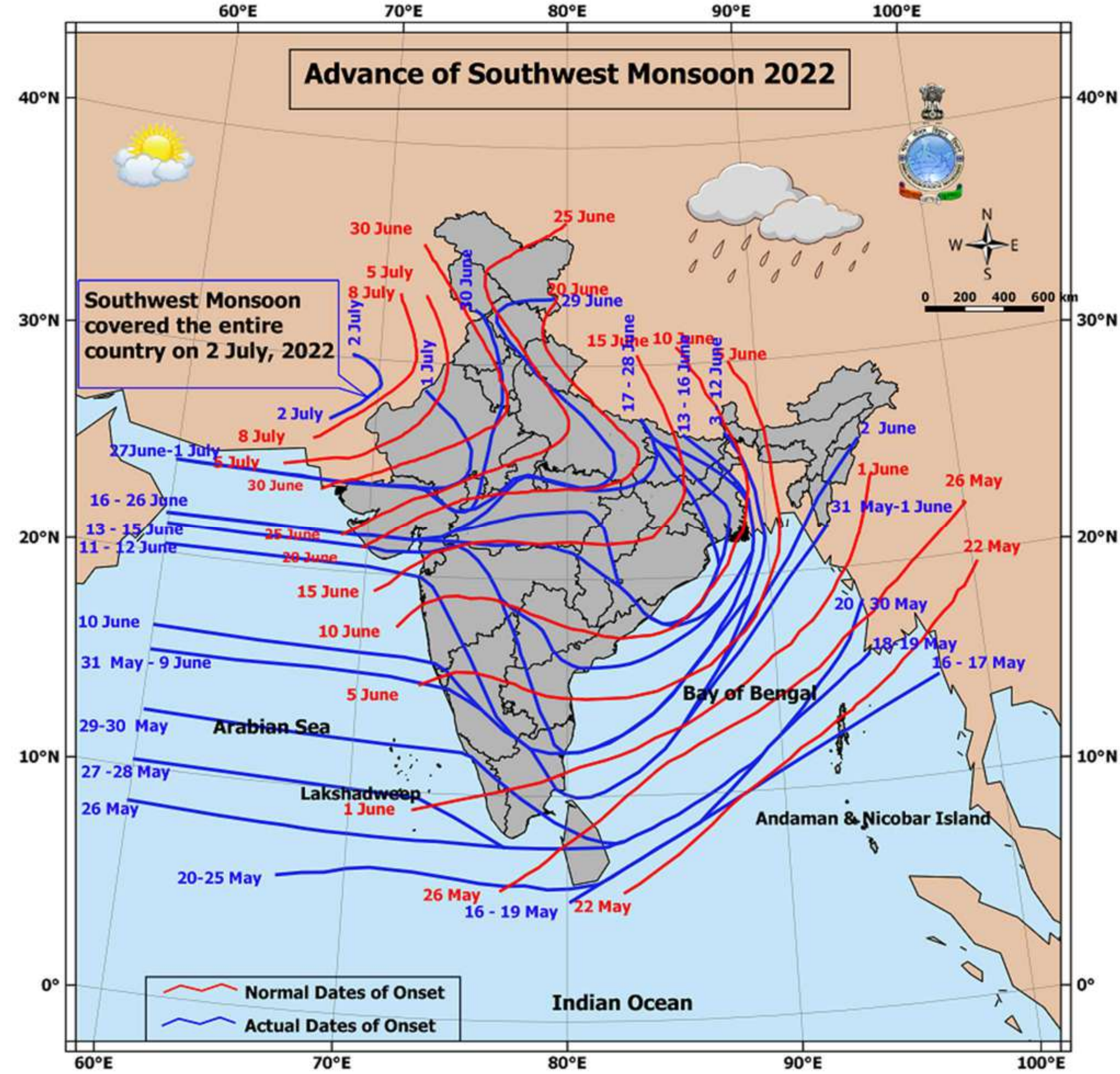
Transition Period: As October-November unfold, the monsoon undergoes a gradual retreat, marking a transition from the rainy season to dry winter conditions. The monsoon trough weakens, making way for a high-pressure system to replace it. This period is associated with climatic changes, including clear skies, a rise in temperature, and oppressive weather during the day, colloquially known as 'October heat.'

Cyclonic Depressions: The retreat of the monsoon is also accompanied by the formation of cyclonic depressions over the Andaman Sea in early November. These depressions, crossing the eastern coasts of India, bring heavy and widespread rainfall. The densely populated deltas of rivers such as the Godavari, Krishna, and Kaveri are frequently impacted by these cyclones, causing significant damage to life and property.

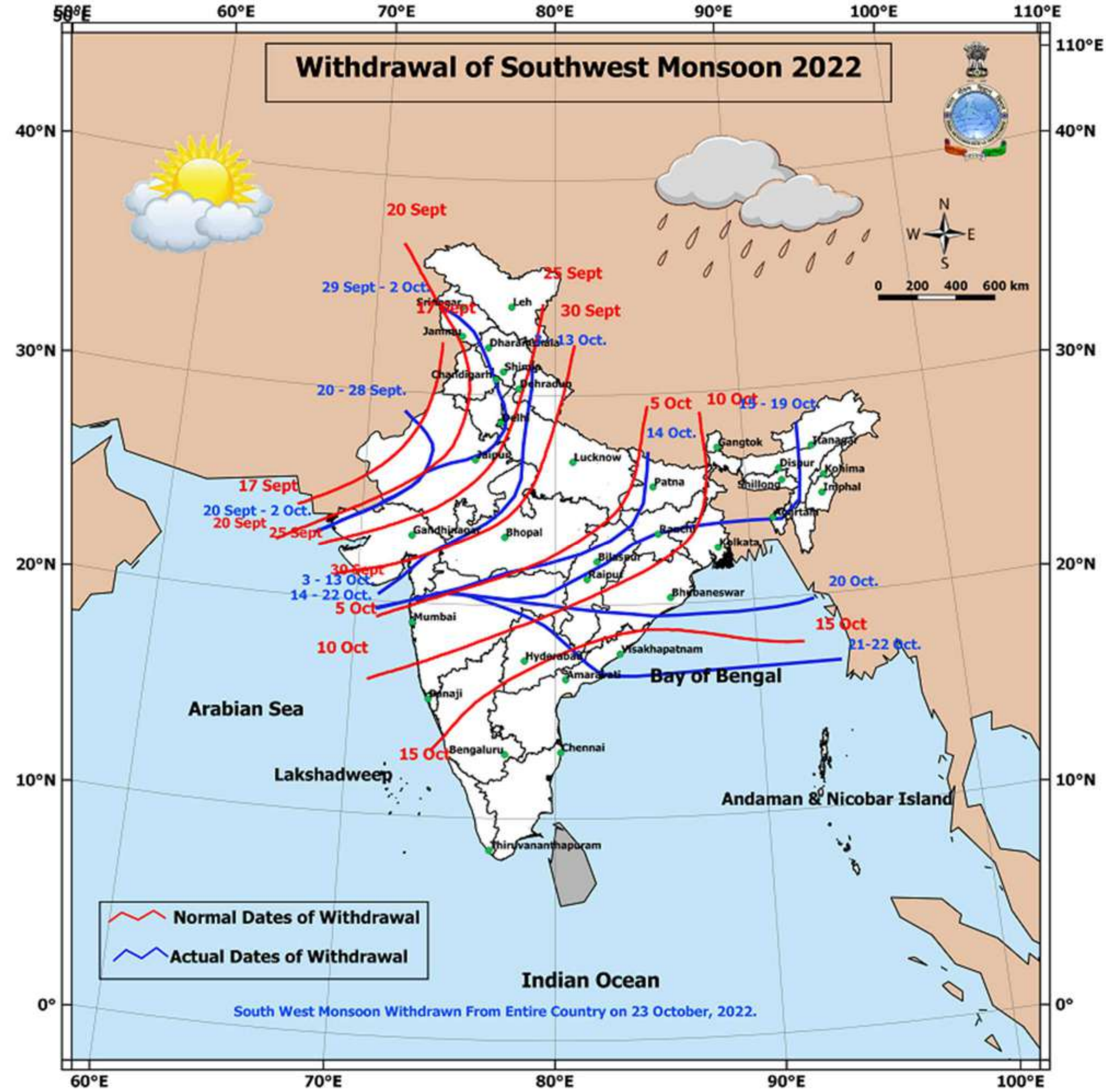
Withdrawal of the Monsoon

a. **Gradual Retreat:** The withdrawal or retreat of the monsoon unfolds gradually, commencing in the northwestern states of India by early September. This gradual withdrawal pattern allows for a more nuanced conclusion to the monsoon season.
b. **Regional Differences in Withdrawal:** Complete Withdrawal from Northern Half: By mid-October, the monsoon has completely withdrawn from the northern half of the peninsula. This signals a significant shift in weather patterns for these regions.
c. **Rapid Withdrawal from Southern Half:** In contrast, the southern half of the peninsula experiences a more rapid withdrawal of the monsoon, reflecting the intricate dynamics of climatic transitions.
d. By early December, the monsoon concludes its retreat from the entire country, paving the way for the next phase of climatic influence.

Island Interaction and Winter Monsoon Influence: The islands off the Indian coast play a unique role in the monsoon cycle. They experience the initial monsoon showers progressively from south to north, starting from the last week of April to the first week of May. Conversely, the withdrawal unfolds progressively from north to south, from the first week of December to the first week of January. By this time, the rest of India falls under the influence of the winter monsoon, shaping weather patterns until the onset of the next monsoon season.


Advance of Southwest Monsoon 2022
Southwest Monsoon covered the entire country on 2 July, 2022
Arabian Sea
Bay of Bengal
Indian Ocean
Lakshadweep
Andaman & Nicobar Island
Normal Dates of Onset
Actual Dates of Onset
60°E
70°E
80°E
90°E
100°E
40°N
30°N
20°N
10°N
0°
0 200 400 600 km

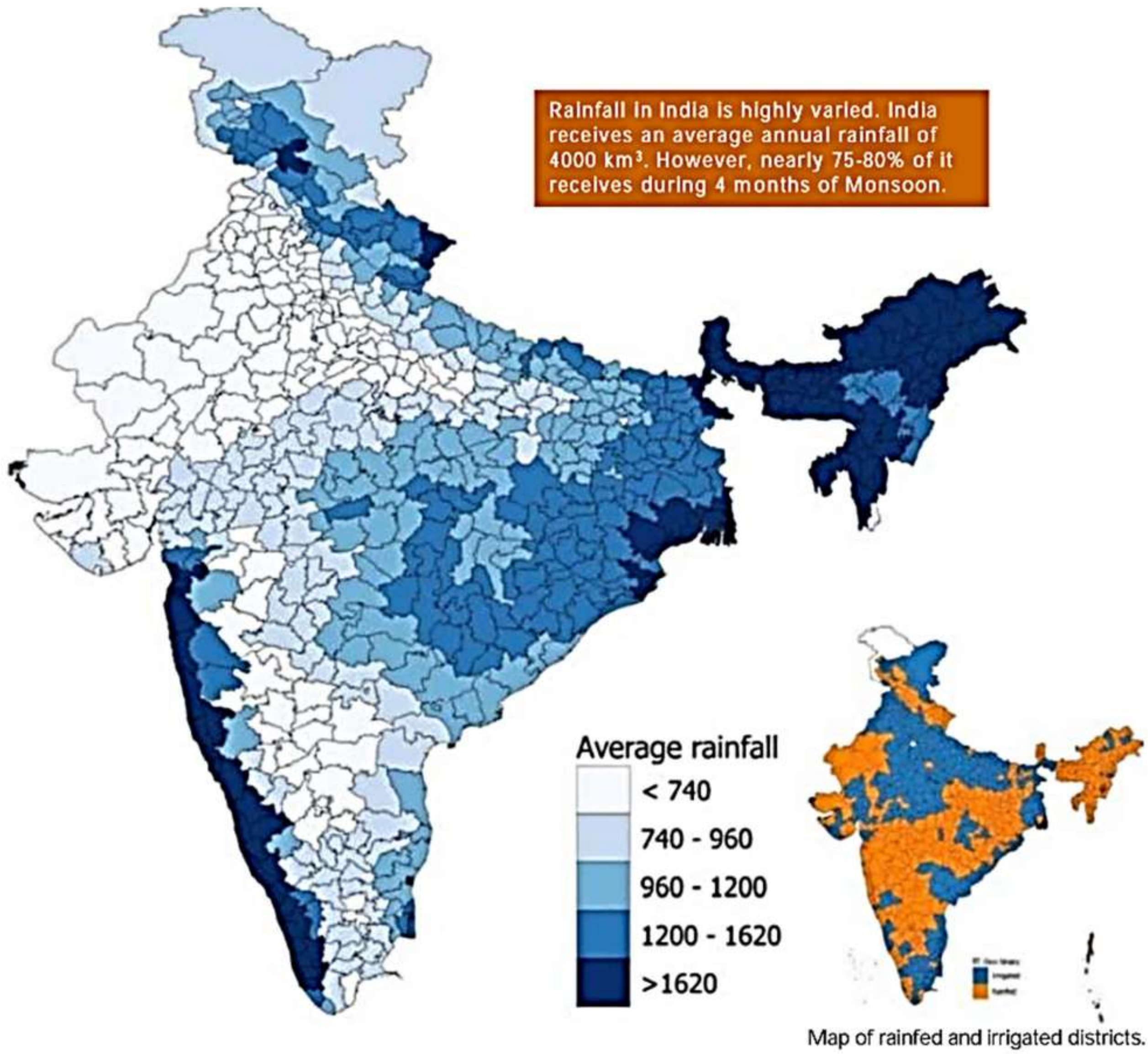
Task for students: Demark the pattern of onset of monsoon in India's map given below


Withdrawal of Southwest Monsoon 2022
Normal Dates of Withdrawal
Actual Dates of Withdrawal
Arabian Sea
Bay of Bengal
Indian Ocean
Lakshadweep
Andaman & Nicobar Island
South West Monsoon Withdrawn From Entire Country on 23 October, 2022.
20 Sept
25 Sept
30 Sept
29 Sept - 2 Oct.
13 Oct.
20 - 28 Sept.
17 Sept
20 Sept - 2 Oct.
20 Sept
3 - 13 Oct.
14 - 22 Oct.
5 Oct
10 Oct
15 Oct
14 Oct.
15 - 19 Oct.
20 Oct.
21-22 Oct.
0 200 400 600 km

Task for students: Demark the pattern of withdrawal of monsoon in India's map given below

Ex. No. 7

DEMARCATION OF RAINFED AREA ON MAP

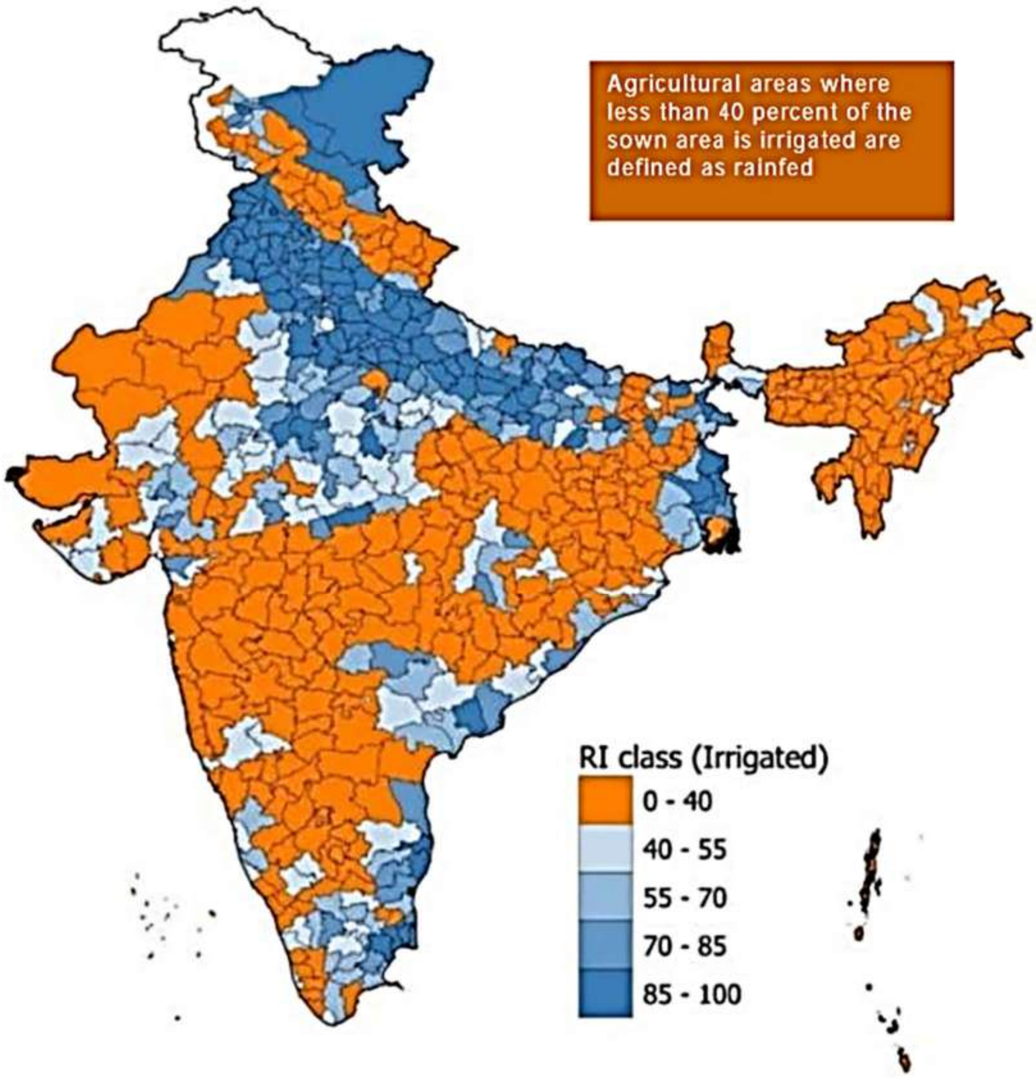


This Map shows average rainfall across India between 1981-2011. The South-West monsoons provide rainfall in the Western Ghats. This creates a rain-shadow region in the mid-south and central regions of India.

Task for students:

1. With the help of above figure and political map of India list out the districts which receives rainfall less than 1200 mm.

2. On below given map of India demark the districts receiving rainfall less than 960 mm.

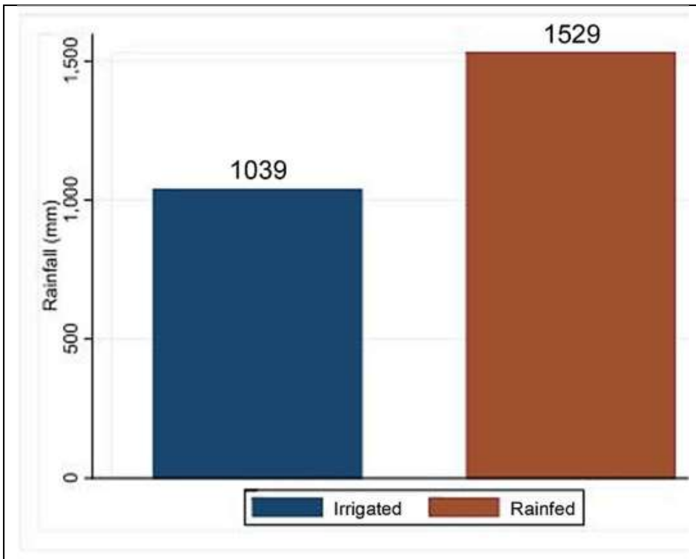


This map shows the variation in rainfed districts by representing them with different grades of orange colour. Irrigated districts are represented by one shade of blue . This shows that several pockets of high rainfedness stand out – one each in western India, central India, eastern India, and north-eastern India.

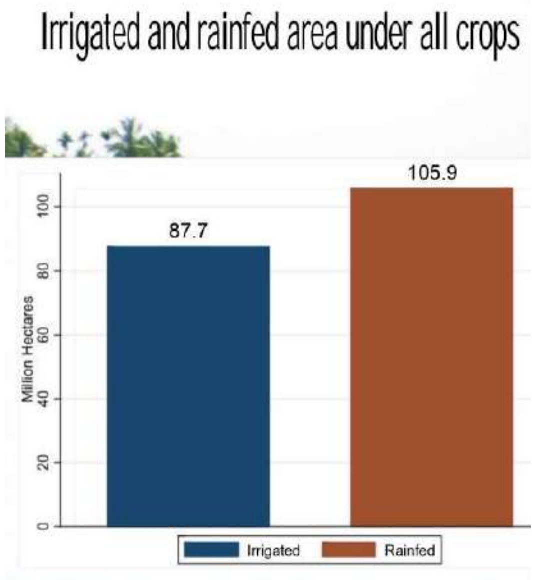
Task for students:

1. With the help of above figure and political map of India list out the districts with less than 40% of irrigated area.

2. On map of India demark the area which comes under less than 40 % irrigated land-



Graph shows average annual rainfall in rainfed and irrigated



Ex. No. 8

STUDIES ON CROPPING PATTERN OF DIFFERENT RAINFED AREAS IN THE COUNTRY

Cropping System Definition: Cropping system may be defined as the order in which the crops are cultivated on a piece of land over a fixed period. In short it is pattern of crops for a given piece of land. – or – It is an important component of farming system. It represents cropping pattern used on a farm and their interaction with farm resources, other farm enterprises and available technology which determine their make-up.

Cropping pattern – Means the yearly sequence and spatial arrangement of crops and follow in an area.

A cultivator selects a cropping system for his land based on the following factors (practical considerations).

1. His interest and right in the land.
2. Extent of land (Size of holdings)
3. Nature of different soils and their extent
4. Climatic conditions.
5. Availability of irrigation facilities.
6. Agronomic characters of crops.
7. Availability of labour, power and his own resources.
8. Food habit and requirements of food and fodder for animals.
9. Marketing facilities.

Classification of cropping systems

I) Monocropping II) <u>Multiple cropping</u> III) Fallowing or fallow in Rotation

1) Parallel multiple cropping 2) Sequential multiple cropping

1) Parallel multiple cropping	2) Sequential multiple cropping
i) Mixed cropping	i) Sequence cropping
ii) Intercropping	a) Double cropping
iii) Relay cropping	b) triple cropping
iv) Alley cropping	c) Quadraple cropping
v) Multistoried cropping	ii) Ratoon cropping or Ratooning

l) Monocropping:

The cropping system in which one major crop is grown on the same land year after years is known as monoculture or single crop system e.g. growing of rice in Konkan region or pearl millet (Bajara) in some parts of Rajasthan.

The reason for monoculture

1. The cultivators have no choice to cultivate many crops as holding is very small.
2. The soil and climatic conditions do not permit successful cultivation of other crops.

3. The crop grown is main article in diet.

Disadvantages of monoculture:

1. Sometimes fertility and productivity of the soils is lowered, if suitable soil management practices are not followed.
2. Soil structure may be deteriorated.
3. Increases infestation of pests, diseases and weeds.

II) Multiple cropping:

The cropping system in which two or more crops are grown either in succession (Sequence) or in association for entire or part period of their life cycles on the same field in a year is called multiple cropping.

1) Parallel Multiple cropping :

When two or more crops are grown in association for part or entire period of their life cycles is known as parallel multiple cropping. It includes following cropping systems.

i) Mixed cropping :

Growing two or more crops simultaneously with no distinct row arrangement is known as mixed cropping. Mixed cropping is common practice in rainfed or dry farming areas. Generally, seeds of legumes like red gram, black gram, green gram, kidney-bean and cow pea etc. or oilseeds like mustard in wheat, Groundnut in cereal crops like Sorghum or pearl millet bajara are mixed.

ii) Intercropping:

It is the cropping system in which two or more crops are grown simultaneously on same piece of land with fixed geometrical, relationship.

Emphasis should be given in intercropping to a legume or an oilseed as one of the components. At present, in intercropping systems, crops still continue to grow at a population less than the optimum recommended for the base crop. But recent studies have shown that the plant density of the base crop can be maintained at optimum and the additional population of the intercrop added for better use of resources.

Intercropping of fast-growing legumes such as cowpea and green gram tends to smoother the weeds and helps the base crop considerably. These additive series are better than the replacement series recommended earlier. The trials conducted by the Central Research Institute for Dryland Agriculture (CRIDA) Hyderabad with Sorghum, Maize. Pearl millet, Pigeon-pea, safflower and wheat as the base crop, the LER of the additive series is greater than those of the replacement series.

In intercropping, since more than one crop is sown together in regularly spaced rows, the row ratio as well as the number of crops is important. Some remunerative intercropping systems are observed in different regions and those are given below in table.

Remunerative intercropping systems with ratios for various regions

Sr. No.	Region	Intercropping system	Row ratio
1)	Semi-arid red soil region of Southern Telengana	Sorghum + Red gram	2:1
2)	Vidarbha region of Maharashtra	Sorghum + red gram Sorghum + red gram	1:1 2:1
3)	Malwa plateau of M.P.	Sorghum + red gram Sorghum + red gram	2:1 1:1
4)	Deccan region of Maharashtra	Bajra + red gram	2:1
5)	Deccan region of Karnataka	Bajra + red gram	2:1
6)	Medium black soils region of Rajkot	Bajra + red gram Groundnut + red gram	4:1 6:1
7)	Sub humid red soil region of Orissa	Rice + red gram	4:2
8)	Sub humid red soil region of Chhotanagpur	Rice + red gram	4:1
9)	Semi-arid red soil of Rayalaseema	Groundnut + red gram	5:1

In all systems listed in above table, it is recommended that full population of the base crop and 50-75% of the companion crop be grown and the customarily recommended fertilizers be applied. For example, in the case of sorghum + red gram intercropping system with 2:1 row ratio, the full seed rate of sorghum is recommended even though the crop occupies only 66% of the area. On the other hand the red gram population is maintained at 50,000 plants/ha.

Fertilizer in intercropping:

The fertilizer schedule for an intercropping system should take care of the needs of both the base crop as well as the inter crop. Generally for a non-legume + legume intercropping system, nitrogen should be as per the requirement of the non legume and phosphates as per the requirements of the legume crop. In a legume + legume intercropping system a slightly higher dose of phosphorus should be applied.

iii) Relay Cropping:

It is the cropping system in which succeeding crop (Next crop) is sown or planted when the first crop (Preceding crop) has reached its physiological maturity stage or before it is ready for harvest e.g. Relay cropping of tobacco in groundnut or relay cropping of Rabi Jowar in groundnut etc

iv) Alley Cropping:

The system of growing Jowar, maize bajara or any other arable crop in the alleys (Passage between two rows) or leguminous shrubs like soo-babul (*Leucaena leucocephala*) is called alley cropping e.g. growing of maize Jowar, bajara, cow pea etc.

in between rows of soo-babul planted at 5 to 10 m. spacing. This system is useful for conservation of moisture, and maintaining fertility of soil in dry farming areas. The loppings of the soo-babul are used as green fodder for animals or spread in between the crop rows as mulch for conservation of soil moisture and after decaying it adds organic matter to the soil.

v) Multistoried cropping:

In this cropping system the crops differing in height and vertical layers of leaf canopies, sunlight requirement and root system are grown together on the same field. Generally, the shorter crops favouring shade and humidity are grown in passage between the row of taller crops which are tolerant to strong sunlight.

e.g. Growing of pine-apple ,sweet potato, black pepper, tapioca, turmeric, ginger etc. in coconut or areca nut.

2) Sequential multiple cropping :

It is the multiple cropping system in which two or more crops are grown in sequence on the same piece of land in a year or over a fixed period .

I) Sequence Cropping:

In this cropping system two or more crops are grown in sequence one after another on the same piece of land in year.

a) Double cropping:

In multiple cropping system the two crops are grown in sequence on the same piece of land in a year. e.g. In assured rainfall areas on moisture retentive soils (Rainfed Crops)

Black gram (K) - Jowar (R)
Black gram (K) - Wheat (R)
Green gram (K) - Wheat or Jowar (R)
Rice (K) - Gram or Wal (R)

Double cropping is possible in receiving more than 750 mm rainfall and with a soil-moisture storage capacity more than 20 cm available water. For example, in high rainfall (1000mm) in Orissa, Bihar and eastern part of U.P. and M.P. the upland rice of about 90 days duration is grown instead of the present cultivars of 120 days or more duration, a second crop could easily be grown in the residual moisture situation. Similarly in the vertisol areas of Malwa in U.P. and Vidarbha and Marathwada in Maharashtra, a change of 140-150 days sorghum to 90-100 days cultivars would provide an opportunity for growing chick-pea or safflower afterwards.

For successful double cropping, the *kharif* crop should be sown early and harvested as early as possible in the areas below the Vidhyan region (Malwa and Vidarbha). But in the northern belt, rabi crops cannot be sown early because of their sensitivity to high temperature.

The double cropping system suggested for different regions.

Region	Cropping System
Sub montain N.W. region	Rice – Wheat Rice – Gram Maize – Wheat Soybean – Wheat
Eastern U.P.	Rice – Gram
Sub humid soil of chhotananagpur	Maize – Safflower Rice – Linseed
Sub humid red soil of Orissa	Rice – horse gram
Sub montain soils of N.E. Punjab	Maize – mustard Maize – gram
Sub montain soils of Jammu region	Maize – mustard
Malwa plateau of M.P.	Maize - safflower Sorghum – Safflower Sorghum – Safflower Sorghum – Gram Soybean – Safflower
Vidarbha region of Maharashtra	Green gram – safflower
Bundelkhand region of U.P.	Cowpea (Fodder – Mustard Sorghum (fodder)- gram

ii) Ratoon cropping or Ratooning:

The Cultivation of crop regrowth after harvest is known as ratoon cropping. Ratooning is one of the important systems of intensive cropping, which implies more than one harvest from one sowing/planting because of regrowth from the basal buds on the stem after the harvest of first crop. Thus, ratooning consists of allowing the stubbles of the original crop to sprout again or to produce the tillers after harvesting and to raise another crop. e.g. Ratooning of hybrid Sorghum, Pearl – millet & Red gram.

III) Fallowing or fallow in rotation:

In scarcity (Dry farming) where the rainfall is very low only two crops are taken in three years as against one crop every year. A fallow years or season is one in which field is not cultivated with any crop left without crop. The field may be left undisturbed in a ploughed condition or kept clean by frequent harrowing. This practice is useful for conservation of soil moisture and maintaining fertility of the soil.

Definitions of important terms in cropping systems:

1. **Base crop**: It is the major crop grown in intercropping system.
2. **Inter crop**: It is the additional crop grown in the space created in inter cropping system.
3. **Main crop**: The major crop grown in mixed cropping system.
4. **Mixed crop/minor/subsidiary crop**: The crop grown by seed mixture in main crop in mixed cropping.
5. **Companion crop:** The crop grown in association in cropping system for complementary effect.
6. **Component crop:** Either of the crops grown in multiple cropping systems.

Multiple cropping Index (MCI):

$$MCI = \frac{\text{Total number of crops + Respective area}}{\text{Total area available for cropping pattern}} \times 100$$

Land Equivalent Ratio (LER)

LER is the relative land area under sole cropping that is required to produce the yield from one hectare in intercropping.

$$LER = \frac{\text{Yield of base crop in intercropping}}{\text{Yield of base crop in sole cropping}} + \frac{\text{Yield of intercrop in intercropping}}{\text{Yield of intercrop in sole cropping}}$$

Cropping Pattern: The selection of crops and their varieties is to be made depending on the soil and rain fail situation in the rained areas. The photo insensitive crops and varieties with shorter duration should be chosen to escape drought of different intensities. There are wide variations, location to location in water availability periods in dryland areas. Thus depending upon water availability following are the different crops and cropping patterns to suit different climatic situations.

Table: Cropping systems followed in different rainfall region

Rainfall (mm)	Broad soil group	Growing season (weeks)	Cropping system
350-650	Alfisols + shallow vertisols, Aridisols + entisols	< 20	Single rainy crop
350-650	Deep aridisols & inceptisols	20	Either rainy or post rainy season crop
350-650	Deep verisols	20	Sole post rainy crop rabi sorghum
650-800	Alfisols, vertisols, inceptisols	20-30	Intercropping
800 & above	Deep vertisols, deep aridsols, entisols	>30	Double cropping

Table: Cropping system suggested by research workers

Arid region	Semiarid region	
	Vertisols (Black)	**Alfisols (Red)**
i. Mono cropping ii. Double cropping iii. Intercropping: Pearl millet + Chickpea Clusterbean + Castor	Double cropping Maize – sorghum (R) Maize – Chickpea/ safflower **Wetter vertisols** (MP) Rice – wheat Green gram – sorghum **Intercropping (MP region)** Maize + pigeonpea, Soybean+ pigeonpea **Dry Vertisols** ***Kharif*** Pearl millet + moth bean, Marvel + moth bean, Sunflower + pigeonpea, Sunflower + groundnut ***Rabi*** safflower + chickpea	*Kharif* predominant Cereal + Pulses, Maize + groundnut, Pigeonpea + castor Sorghum + pigeonpea Pigeonpea +groundnut

Table: Crop planning as per the soil depth

S.N.	Soil type	Depth (cm)	Suggested cropping
1.	Very shallow soils	7.5	a) Fruit crops – Ber , Aonla, Pomegranate, Tamarind b) Improved grasses–Madras anjan, Marvel–8, stylo
2.	Shallow soil	7.5 to 22.5	Field crops – horse gram, mothbean, castor Pearl millet + pigeonpea intercropping
3.	Medium deep soil	a) 22.5 to 45	Sunflower + pigeonpea intercropping Pearl millet+ pigeonpea intercropping
		b) 45 to 60	Sunflower, groundnut, castor, setaria – *kharif* Pearl millet + pigeonpea intercropping, sole cropping of pearl millet, sunflower, green gram, groundnut in *kharif* Sole crop of sorghum, safflower, chickpea
		c) 60 to 90	Double cropping green gram – sorghum Double cropping pearl millet – chickpea sole crop of sorghum, safflower, chickpea and sunflower
4	Deep soil	More than 90	Green gram – sorghum, sunflower – chickpea sole crop of sorghum, safflower, chickpea and sunflower

Stable intercropping systems for rained areas:

Scarcity Zone: - Bajra + Tur in 2: 1 row proportion

Assured rain : - Sorghum + Mung / Udid in 2: 1 row proportion fall zone.

Cotton + Mung / Udid in 1: 1 row proportion

Cotton + Tur in 8: 2 row proportion

Sorghum + Tur in 2: 1 row proportion.

Tur + Mung / Udid in 1: 3 row proportion.

Cropping pattern of rained areas:

Monoculture	Scarcity zone	Pearl millet, red gram, green gram, black	
		gram, Horse gram, groundnut	
		Rabi : Jowar Safflower	
	Assured rainfall	Cotton, sorghum, red gram, black gram,	
		green gram, soybean, sunflower	
Double cropping	Scarcity zone	Kharif crops Mung / Urid Mung / Urid Sunflower , Bajra, Bajra	Rabi crops Safflower Jowar, Gram Gram , Safflower
	Assured rainfall zone	Paddy Soybean Mung/Urid Mung/Urid Sunflower	Gram Safflower Jowar Safflower Gram
	Irrigated areas	Jowar Jowar Maize Gr. nut Gr. nut	Wheat Gram Wheat Jowar Sunflower

Task for students: Write different cropping system you have identified at the BUAT, Banda farm

Ex. No. 9

STUDIES ON AGRICULTURE AND CROPPING PATTERN OF BUNDELKHAND REGION

Bundelkhand Region Map

Table 1. Irrigated area as percentage of total sown area in UP Bundelkhand (2002-03) and MP Bundelkhand (2005-06)

	Total area sown*(ha)	Total area irrigated(ha)**	% total area sown that is irrigated
Jhansi	465240	223027	47.9
Lalitpur	385426	210013	54.5
Jalaun	437205	191399	43.8
Hamirpur	352531	111508	31.6
Mahoba	292021	114944	39.4
Banda	422544	174065	41.2
Chitrakoot	193321	53450	27.6
UP Bundelkhand	**2548288**	**1078406**	**42.3**
UP	**25424605**	**18523956**	**72.8**
Datia	228465	136302	59.6
Chhatarpur	511319	226581	44.3
Tikamgarh	370642	206778	55.8
Panna	297655	84420	28.4
Damoh	398648	114138	28.6
Sagar	710690	236635	33.3
MP Bundelkhand	**2517419**	**1004854**	**39.9**
MP	**19607592**	**5878311**	**30**

Source: District-wise Land Use Statistics, Ministry of Agriculture, Government of India, May 2008. Percentages rounded off.

*Total sown land includes area sown more than once; the area is counted as many times as there are sowings in a year.

**Total irrigated area is the total area under crops, irrigated once and/or more than once in a year. Area covered by any source of irrigation is considered irrigated area.

Table 2. Cropping intensity in UP Bundelkhand (2002-03) and MP Bundelkhand (2005-06)

	Net area sown in year(ha)	Area sown more than once in year (ha)	Cropping intensity (%)
Jhansi	346423	118817	134
Lalitpur	265712	119714	145
Jalaun	348445	88760	125
Hamirpur	302514	50017	117
Mahoba	244581	47440	119
Banda	348600	73944	121
Chitrakoot	172052	21269	112
UP Bundelkhand	2028327	519961	126
UP	16749534	8675071	152
Datia	197242	31223	116
Chhatarpur	403863	107456	127
Tikamgarh	240951	129691	154
Panna	251523	46132	118
Damoh	311037	87611	128
Sagar	539003	171687	132
MP Bundelkhand	1943619	573800	130
MP	14970966	4636626	131

Source: District-wise Land Use Statistics, Ministry of Agriculture, Government of India, May 2008. Figures for area sown more than once a year derived by subtracting net sown area figures from total sown area figures in Table 1 above. Percentages rounded off.

The district-wise cropping pattern in Uttar Pradesh is depicted in the Table given below. Its shows that the highest cropping intensity was reported in the Lalitpur followed by Jhansi and Banda district. The maximum area covered by wheat, gram, other pulses and sesame. These crops are suitable for this region because of low water requirement and low production cost except wheat. The cropping intensity was higher in Tikamgarh, Damoh and Sagar districts even more than state average of Madhya Pradesh. The maximum area is under wheat, soyabean, gram, other pulses and sesamum in all the districts in the region. Surprisingly, the share of rice is over 19 per cent in Panna district where groundwater table is declining rapidly during last decade. Rice is water guzzling crop which should be discouraged in this water scarce region.

Table 3. District-wise cropping pattern(per cent) in Bundelkhand region of Uttar Pradesh, 2014-15

Crop	Banda	Chitra-koot	Hamir-pur	Jalaun	Jhansi	Lalit-pur	Mahoba	All Uttar Pradesh
Rice	12.15	6.70	0.02	0.38	2.82	0.24	0.01	23.47
Jowar	5.36	6.03	4.20	1.60	0.14	0.02	0.53	0.62
Bajra	0.69	7.97	0.12	3.29	0.00	0.00	0.00	3.72
Maize	0.00	0.00	0.02	0.00	0.12	3.29	0.00	2.64
Wheat	35.92	37.12	29.31	35.94	28.45	34.64	20.40	38.43
Barley	0.18	1.80	1.32	1.93	3.63	1.94	2.16	0.60
Other Cereals and Millets	0.00	0.02	0.00	0.00	0.04	0.00	0.00	0.13
Gram	20.14	17.89	18.78	8.40	9.46	2.23	18.09	2.04
Arhar (Tur)	4.28	5.71	4.26	1.21	0.09	0.00	0.91	1.05
Other Pulses	11.52	8.87	20.48	25.43	33.39	43.28	37.24	5.57
Sugarcane	0.10	0.11	1.47	0.29	0.03	0.01	1.14	8.47
Other Sugar	0.00	0.00	0.03	0.02	0.01	0.00	0.00	0.12
Total Condiments and Spices	0.04	0.02	0.13	0.03	0.01	0.15	0.04	0.24
Total Fruits	0.01	0.01	0.00	0.00	0.04	0.02	0.00	1.14
Total Vegetables	0.43	0.75	0.57	1.75	0.89	0.51	0.61	3.24
Groundnut	0.19	0.04	0.06	0.00	5.40	2.08	3.97	0.39
Sesamum	6.44	2.85	13.69	15.81	12.77	1.23	10.55	1.46
Rapeseed and Mustard	0.85	2.93	4.27	2.58	1.54	0.76	1.97	2.23
Linseed	0.86	0.31	0.55	0.05	0.03	0.00	2.05	0.09
Soyabean	0.01	0.00	0.00	0.01	0.31	9.56	0.10	0.21
Other Oilseeds	0.02	0.00	0.04	0.04	0.07	0.00	0.01	0.01
Total Fibres	0.03	0.06	0.10	0.02	0.01	0.00	0.03	0.03
Total Drugs, Narcotics and Plantation Crops	0.00	0.00	0.13	0.60	0.48	0.00	0.13	0.97
Fodder Crops	0.78	0.79	0.44	0.50	0.13	0.04	0.02	2.93
Green Manure	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.06
Other Non-Food Crops	0.00	0.00	0.00	0.08	0.12	0.00	0.02	0.16
Cropping intensity	130	113	128	125	165	180	143	158

Source: Authors estimates based on data from Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India data accessed on 31-3-2017 from http://agcensus.dacnet.nic.in

Task for students:

1. **With the help of tables 1 given in this exercise Summarise the irrigation condition of Bundelkhand region in about 200 words.**

2. **With the help of tables 2 given in this exercise Summarise the cropping intensity of Bundelkhand region in about 200 words.**

3. **With the help of tables 3 given in this exercise Summarise the cropping pattern of Bundelkhand region in about 200 words.**

Ex. No. 10

STUDIES ON INTERPRETATION OF METEOROLOGICAL DATA (RAINFALL, TEMPERATURE, HUMIDITY etc.)

In this exercise, the way of description and interpretation of relevant meteorological data is summarized on the basis of some weather parameters. The example of one research experiment is noted here. The study was conducted at the CoA Farm, Banda University of Agriculture & Technology, Banda-210001, Uttar Pradesh, India, during the Kharif season of 2022. The research field is located between latitude 24° 53' and 25° 55'N and longitudes 80° 07' and 81° 34' E, with an altitude of 168 meters above sea level. This region falls under agro-climatic zone- 8 (Central Plateaus & Hills Region) of India.

Weather data during experimentation

Met. Weeks No.	Month	Temperature (°C)		RH (%)	Average Wind Speed (km/hr)	Rainfall (mm)	ET (mm)
		Min.	Max.				
31	31 July-6 Aug 2022	27.71	35	82.69	2.99	23.25	0
32	7-13 Aug 2022	26.85	32.42	88.19	5.77	63	0
33	14-20 Aug 2022	26.42	33.14	85.68	5.72	54	4.4
34	21-27 Aug 2022	26.28	31.71	90.69	4.84	5.5	0
35	28-3 Aug 2022	27.71	35.42	85.57	2.56	1.5	0
36	4 Aug-10 Sep 2022	27.5	37	79.55	3.18	0.5	0
37	11-17 Sep 22	26.14	32.25	87.92	6.47	65.25	0
38	18-24 Sep 22	25.42	32	90.48	2.86	101	0
39	25 Sep- 1 Oct 22	25.57	35.28	81.76	1.86	16.75	0
40	2-9 Oct 22	25.28	33.42	86.08	3.19	56	0
41	10-16 Oct 22	23.71	32.85	84.38	2.24	57	14.8
42	17-23 Oct 22	21.57	34.14	66.83	2.34	0	13.9
43	24-30 Oct 22	19.42	33.71	62.53	2.22	0	1.7

Interpretation on Climate and weather data

The Bundelkhand region is characterized by a hot and semi-humid climate, which often experiences droughts or drought-like conditions. During the Kharif season, the maximum temperature in this region can reach up to 41°C, while in winter, the minimum temperature can drop to 6°C. The region receives about 90% of its annual rainfall between June and October, with the highest rainfall occurring in the months of July and August. On average, the Bundelkhand region receives around 850 mm of rainfall annually, but due to the undulated topography, a significant amount of water is lost to runoff. In the winter months, from November to March, the region receives occasional rain showers. During the Kharif season, which corresponds to the crop period, there are typically 8 rainy days. The recorded minimum temperature during this crop period is around 20°C, while the maximum temperature reaches up to 42°C. These climatic conditions play a crucial role in determining the crop growth and agricultural practices in the Bundelkhand region.

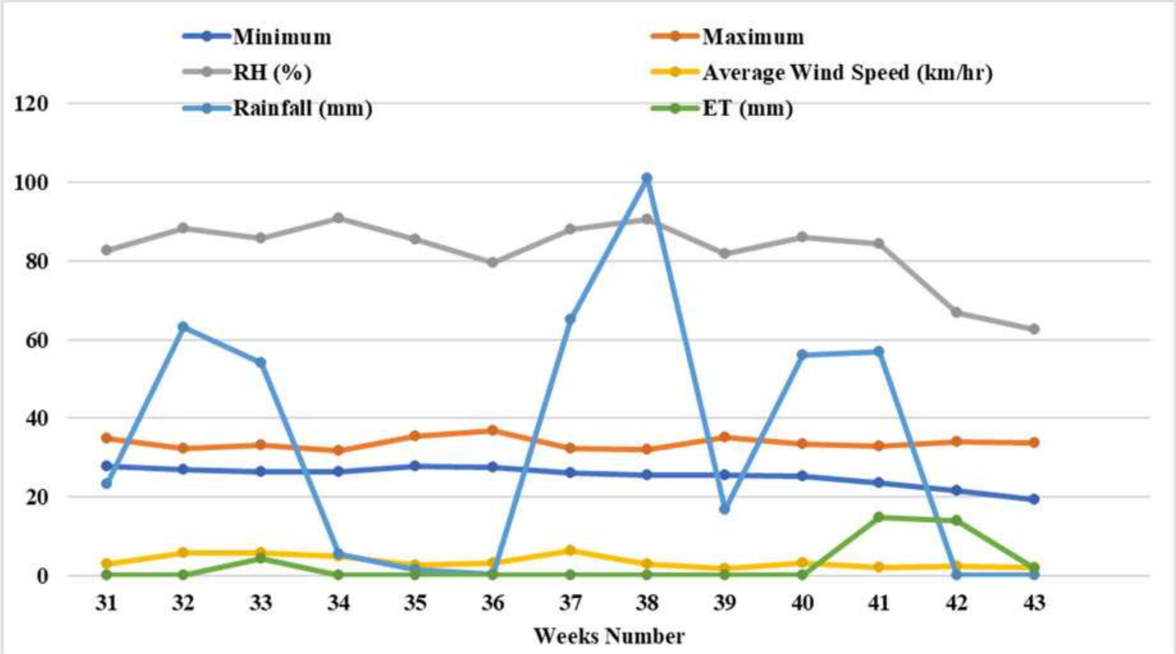


Fig. Graphical representation of weather data

Task for students: Collect meteorological data from the observatory of above parameters for the last years kharif season, fill it in the below given table and make interpretations on it.

Weather data during experimentation

Met. Weeks No.	Month	Temperature (°C)		RH (%)	Average Wind Speed (km/hr)	Rainfall (mm)	ET (mm)
		Min.	Max.				
31							
32							
33							
34							
35							
36							
37							
38							
39							
40							
41							
42							
43							

Ex. No. 11

STUDY OF EFFECTIVE RAINFALL AND ITS CALCULATIONS

Effective rainfall:

Effective rainfall is a part of rainfall available for the consumptive use of the crop. Part of the rain may be lost as surface runoff, deep percolation below the root zone of the crop. All quantity of rainfall that falls is not used by the crops for growth and yield but a part of it is wasted by various ways. In its simplest meaning, effective rainfall means useful or utilizable rainfall. Or It is that portion of total rainfall, which directly satisfies crop water needs Effective rainfall means useful or utilizable rainfall. Rainfall is not necessarily useful or desirable at the time, rate or amount in which it is received, some of it may be avoidably wasted, while some may even be distinctive. Dastane (1974) has defined the annual or seasonal effective rainfall as that part of the total annual or seasonal rainfall which is useful directly and or indirectly for crop production at the site where it falls, but without pumping.

Ineffective rainfall is that portion which is lost by surface runoff, unnecessary deep percolation, the moisture remaining in soil after the harvest of crop and which is not useful to second crop. When rainfall is of high intensity, only a portion of rainfall can enter the soil and stored in the root zone. In case of light rains of low intensity depending on the amount of moisture already present in the root zone of crop, even an entire rainfall may be effective rainfall.

Water requirement of crops (WR):

It is the quantity of water regardless of source needed for normal crop growth and yield in a period of time at a place and may be supplied by precipitation or by irrigation or by both.

Water requirement includes the losses due to **ET or CU** (Consumptive use) plus the losses during the application of irrigation water in the field (unavoidable loss i.e. percolation, seepage and runoff) and quantity of water required for special operations such as land preparation, transplanting, leaching etc.

W.R. = CU + Application loss + Water needed for special operations.

Water requirement (W.R.) is therefore, a demand and supply would consist of contribution from irrigation water (IR) Effective rainfall (ER) and soil profile contributions including that from shallow water table (s) WR = IR + ER + S

Under field conditions, it is difficult to determine evaporation and transpiration separately. They are estimated together as evapotraspiration (ET)

Irrigation requirement = Water requirement – (Effective rainfall +Ground water contribution)

(IR) = (WR) - (ER + S)

Factors influencing effective rainfall:

Several factors influence the proportion of effective rainfall and these may act singly or collectively. The factors influencing, infiltration runoff and E.T. affects the value of effective rainfall.

1. **Rainfall characteristics**:
    a. High intensity of rainfall - Less effective rainfall
    b. More duration of rainfall - Less effective rainfall
    c. Well distributed rainfall - More effective rainfall with light showers.

Greater quantities as well as intensities of rainfall normally reduce the effective fraction, increasing run off and lessening infiltration. Similarly, uneven distribution decreases the extent of effective rainfall.

A well-distributed rainfall in frequent light showers is more conductive to crop growth than heavy rainfall. In India, **an intensity, frequency and amount of rainfall are higher during July and August** and hence **effective fraction** of rainfall is **very low**. From **November to April**, however **most of rainfall is effective** due to its **low intensity**, frequency and amount. It is assumed that, in India **70%** of an average rainfall (seasonal) to be effective in arid and semi-arid regions while **50%** is considered as effective in humid regions.

2. Land Slope: -

a. Leveled land - more effective rainfall
b. Sloppy land - less effective rainfall more runoff
c. Ploughed land - More effective rainfall
d. Vegetative cover - Less runoff, more effective rainfall

The slope of the land has a profound influence on the time available for the rain water to infiltrate into the soil. Water stays longer on flat and leveled land and thus has a longer opportunity time than on sloping land where there is a rapid runoff. Slopping, rolling and undulating lands thus reduces infiltration and consequently effectiveness of rainfall.

3. Characteristics of the soil:

a. Infiltration rate- high infiltration rate - more effective rainfall
b. Storage capacity - More storage capacity - more effective rainfall (Depth of soil)
c. Initial water content - high initial water content then less will be the effective rainfall

The soil properties influencing infiltration, moisture retention, release and movement of water affect the degree of effective rainfall. High infiltration and hydraulic conductivity of soil enhance infiltration and reduce runoff. The fraction of effective rainfall increases with- increased water holding capacity, depth, structure and organic matter content. The moisture content of soil at the time of occurrence of rain affects the effective rainfall considerably, the higher moisture content, lower infiltration rate and higher surface runoff. The proportion of effective rainfall is lower in irrigated area than un-irrigated areas.

4. Ground Water table:

The upper surface of the zone of saturation is called the water table. The amount of effective rainfall is greater when the water table is deep. More roof zone depth complete ground cover Active stage of growth - More uptake of water more will be effective rainfall. Effective rainfall is more when water table is deep than shallow. This is due to the movement of water upwards in soil by **capillary,** thus reducing the deficit moisture.

5. Management Practices:

Bunding, terracing, contour tillage, ridging and mulching reduce runoff and increase effective rainfall. Any management practices which influenced runoff, infiltration, hydraulic conductivity or anti transpiration also influences the degree of effective rainfall.

6. Crop Characteristics:

Crop characteristics influencing the rate of water uptake are degree of ground cover, rooting depth and stage of crop. Deep-rooted crop increase the proportion of effective rainfall. Rainfall just before harvesting is ineffective for most of crops. The effective rainfall is directly proportional to the rate of water uptake by the plant.

7. Carryover soil moisture:

It is the moisture stored in crop root zone between cropping season or before the crop is planted. The contribution of the rain occurring just prior to sowing may be equivalent to one full irrigation and this is generally deducted in determining seasonal irrigation requirement. It is the moisture stored in the crop root zone depths between cropping seasons or before the crop is planted. This moisture is available to meet the consumptive water needs of the crop.

Some empirical relationship for estimating effective rainfall for crops other than rice following practice for estimation is applicable.

1. Effective rainfall is taken as 70 % of seasonal rainfall
2. Effective rainfall is taken as taken as mean rainfall neglecting 75 mm in one day 125 mm in 10 days.
3. Effective rainfall is taken as the lowest rainfall occurring in three out of five years

The Kharif season is divided into 10 days period. Rainfall in each period, exceeding the consumptive use of the crop is treated as ineffective. Generally rainfall in June less than 10 mm and more than 100 mm is ineffective. In other month July, August, September rainfall less than 2.5 mm per day, more than 50 mm per day like 75 mm and rainfall in excess of reference crop evapotraspiration are ineffective.

Ex. No. 12 & 13

STUDIES ON DIFFERENT SOIL AND MOISTURE CONSERVATION PRACTICES FOR MITIGATING MOISTURE STRESS

Techniques of soil and water conservation:

Soil and water conservation methods aim at encouraging water to infiltrate into the soil, reduce its velocity and check run off losses. The loss of soil and water under natural vegetation is the lowest. But lands must be cultivated and grown with crops to produce food. This can be done without much harm to the soil if proper soil and water conservation methods are followed. Such methods aim at encouraging water to infiltrate into the soil, reduce its velocity and check run off losses.

Annual rainfall in several parts of drylands is sufficient for one or more crops per year. Erratic and high intensity storms leads to runoff and erosion. The effective rainfall may be 65 per cm or sometimes less than 50 per cent. Hence, soil management practices have to be tailored to store and conserve as much rainfall as possible by reducing the runoff and increasing storage capacity of soil profile. A number of simple technologies have been developed to prevent or reduce water losses and to increase water intake.

A. Agronomical /cultural practices :

1. Strip cropping
2. Tillage
3. Fallowing
4. Mulching
5. Crop rotation
6. Contour cultivation
7. Cover management
8. Planting of grasses for stabilizing bunds
9. Planting of trees and afforestation
10. Selection of suitable cropping and alternate land use systems
11. Micro-watersheds
12. Use of antitranspirant

B. Mechanical practices :

1. Contour bunding
2. Graded bunding or channel terraces
3. Bench terracing
4. *Puetorican* type bench terracing
5. Conservation bench terracing (CBT):
6. Compartmental bunding:
7. Broad base terracing
8. Zing terracing

9. Broad bed furrow system
10. Trenching
11. Dead furrow

Agronomical practices:

1. **Strip cropping:** This consist of growing erosion permitting crop and erosion resisting crops in alternate strips. The erosion permitting crops are cotton, jowar, bajra etc., which are grown in rows and which allow the runoff water to flow freely within the row. The erosion resisting crops are mostly legume like groundnut, matki, soybean, which spread and cover the soil and do not allow runoff water carry much soil with it.. The soil which flows from the strip growing erosion permitting crops is caught by the alternating strips of erosion resisting crops.
2. **Tillage: -** The surface soil should be kept open for the entry of water through the soil surface. Offseason shallow tillage aids in increasing rain water infiltration besides decreasing weed problems. Deep tillage once in 2 to 3 years has been extremely beneficial in shallow red soils of Anantapur (AP). Contour cultivation is effective in reducing soil and water loss. On red soils, crusting is a serious constraint to seedling emergence and soil and water conservation. Shallow tillage during initial stage of crop with intercultivation implements will be effective in breaking up the crust and improving infiltration. Unfortunately, all the tillage practices that increase entry of water also tend to increase evaporation losses from surface soil. This is the major component of storage inefficiency in soils with high water holding capacity.
3. **Fallowing:-** Traditional dryland cropping systems of deep vertisols involve leaving the land fallow during rainy season and raise crops only during post rainy season on profile stored soil moisture. The main intention of fallowing is to provide sufficient moisture for the main post rainy season crop. The monsoon rains, even in drought years, usually exceeds the storage capacity of root zone soil depth. This system probably provides some level of stability in the traditional system, though in years of well distributed rainfall, the chance of harvesting a good crop is lost. Probably poor ***drainage,*** tillage problems (workability of soil) and weed control have forced the farmer to adopt ***post rainy*** season cropping. Since the soil has to be kept weed free during rainy season. & problem of erosion and runoff increases considerably.
4. **Mulching :** A mulch natural or artificially applied layer of plant residues or other materials on the surface of the soil with the object of moisture conservation, temperature control, prevention of surface compaction, reduction of runoff and erosion, Improvement in soil structure and weed control.
5. **Crop rotation:** Continues growing of jowar or bajra crop causes more erosion, but if followed by a legume crop, which cover the soil, it causes less erosion and maintains soil fertility.

6. **Contour cultivation:** Tillage operation viz., Ploughing, harrowing, sowing and intercultural should be done across the slop of land. This helps more infiltration of water, less run off and erosion and give higher crop yield.

Fig. Strip Cropping

Fig. Tillage

Fig. Mulching

7. **Cover management:** This practice ensure continuous cover on the soil surface through cultivation of close growing and erosion resisting crops, grasses and shrubs to reduce erosion and improve water conservation. Among the field crops, legumes and forage crops provide better cover for interception of kinetic energy of rain drops and interruption of run-off. Nearness of the canopy to land surface and extent of cover determine the effectiveness of the crop. Mixed cropping systems of low-canopy legumes with widely spaced crops is a most suitable option, which provides a better and continuous cover to ground, protection against beating action of rain drops and ensure at least one crop under adverse climatic conditions, particularly in semi-arid and hilly regions against complete failure of the crops. The cover crops such as greengram, blackgram, groundnut, soybean, sannhemp and *dhaincha* restore soil fertility, control weeds, conserve rainwater, reduce energy and costs, besides reducing soil erosion and improving soil morphological characters. Intercropping of low canopy legumes such as groundnut, greengram, blackgram, soybean and cowpea in wider inter-row spaces of crops like maize, sorghum, cotton, castor and pigeonpea provide sufficient cover on the ground; thereby reduce erosion hazards apart from biological insurance to increase productivity of rainfed arable lands.
8. **Planting of grasses for stabilizing bunds:** Grasses should be grown on bunds which are not suitable for cultivation, both for checking erosion and providing pasture for cattle.
9. **Planting of trees and afforestation:** Forest conserve soil and water quite effectively. They not only obstruct the floe of water, but the falling leaves provide organic matter which increase the water holding capacity of the soil. If tree planted is done in the planned manner in open areas, it will serve as good wind break and if done along the banks of stream and river, it will regulate their flow.
10. **Selection of suitable cropping and alternate land use systems**: Cropping sequence and crop rotation have considerable bearing on production and conservation. Based on the availability of rainfall, soil type, length of growing season and land topography, cropping systems and alternate land use systems recommended for different agro-climatic conditions have to be exploited for effective conservation of rain water and its utilization. Agro-forestry has become an important technology for resource poor small farmers especially under dry land conditions. Alley cropping is another approach for effective use of limited resources. Putting the land under grasses as per land capability classification and efficient management of existing grazing land may contribute significantly towards efficient utilization of limited natural resources.
11. **Micro-watersheds:** Land configurations have been developed in which run-off water from un-cropped area or parts of the field is concentrated in strips or adjoining plots in which crops are planted. The crops are sown in the narrow strips or in the inter-plot between wide strips, which are treated to act as miniature watershed for the cropped areas. The catchment areas compacted and designed to create slope to

increase run-off to the cropped areas. The relative width of water shedding strips and of the crop producing strips depend upon the amount of expected annual precipitation. The usual ratios vary from 2:1 to 4:1. Ground covers of plastic films, rubber and metal sheeting materials and waterproofing and stabilizing soil surfaces by spraying with low cost materials can be used to increase the run-off from the catchment area.

Fig. Agroforestry (Agri-Horti System)

Fig. Sccops

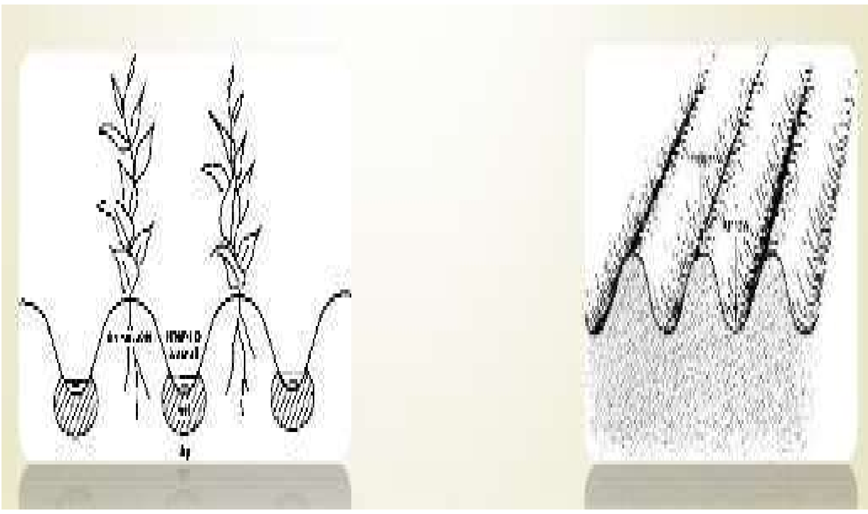


Fig. Ridges and Furros

12. **Use of antitrasparant: -** Approximately 99% of the water taken up by plant roots is transpired to the atmosphere through stomatal pores in the leaves. Use of antitranspirant reduces the transpiration loses and reduces the loss of water from plant.

Mechanical practices:

The above measures control erosion by good management practices. Bunding, terracing, *gully* or *nala* control, and construction of tanks and bandharas are mechanical measures requiring engineering techniques and structures. They reduce run off and impound water for longer time to help infiltration into the soil. Their construction and design will depend upon rainfall, soil slope and such other factors. These measures are costly but if properly maintained will improve the land over a long period of time.

Mechanical or engineering measures are needed on agricultural lands to supplement agronomical practices when slope becomes steeper or velocity of the run-off and discharge become high. These measures help in dissipating energy of flowing water by reducing its velocity with permissible limits, increasing the time of concentration to conserve more run-off water into the soil and minimizing soil erosion by reducing length and/or degree of slope. On agricultural land, land configuration measures include contour bunding, graded bunding, bench terracing, conservation bench terracing, conservation ditching, grassed waterways and graded trenching.

1. **Contour bunding**: Bunding is the most effective and widely practiced field measure for controlling run-off and reducing soil erosion. Contour bunding is defined as series of mechanical barriers across the land slope on contour line. Each contour bund acts as a barrier to the flow of water. Thus, the water flow is restricted and there is possibility of impounding water which infiltrate overtime in the soil profile. This type of bunding is recommended for rolling lands with the slope of less than 6 % and flat land with scanty or erratic rainfall. **In soil of very shallow depth (< 7.5 cm) contour bunding is not suitable**. The design of contour bund involves spacing of bunds, its cross section, which vary with slope, rainfall, soil texture and depth of soil profile. Surplusing arrangements for contour bunds are necessary in high rainfall areas to drain-off excess run-off water safely out of land without causing erosion.
2. **Graded bunding:** Graded bunds consist of small bunds constructed with a slope of 0.3 to 0.5 % in order to dispose of excess water through the graded channels which lead to naturally depressed area of the land. These are recommended for area more than 600 mm rainfall having highly impermeable soils. The purpose of graded bunding is to make run-off water to trickle rather than to rush out. Graded bunding is restricted to 6 % slope and in specific cases it may be extended to a slope of 10 %. The height of bund should be at least 45cm and top width may vary with height of the bund. Grassed water ways are necessary to prevent soil erosion downstream and failure of the bunds.
3. **Bench terracing:** A terrace is a ridge or embankment of earth constructed across the slope to control run-off and minimize soil erosion. This is one of the most widely

adopted mechanical measures of soil moisture conservation suitable for hilly areas with a slope of 6-33%. Bench terracing consist of step like fields or benches constructed along contours by cut and fill method to reduce length as well as degree of slope for either impounding rain water for cultivation or channeling it for safe disposal. In addition, it helps in promoting uniform distribution of soil moisture, irrigation water and controlling soil erosion and thereby increasing productivity of land. Depending upon the soil, climate, topography and crop requirements, bench terraces may be of table top or level type, outwardly sloping or inwardly sloping with mild longitudinal grades for run-off disposal. Cultivation is carried out on the leveled field.

4. ***Puetorican* type bench terracing:** *Puetorican* or natural type bench terrace comprises laying an earthen bund (30 to 40 cm height) or a vegetative barrier of 1.0 m width along the contour at 1.0 m vertical interval. The space between barriers is cultivated which results in the formation of terraces through induced deposition of soil along the barriers in about 4 to 5 years. This fairly less costly practice than bench terracing on slopes up to 7-12% and costs 64 to 76% of the conventional cost of bench terracing. The vegetative barriers should be established by staggered planting of 2 to 3 lines of grasses across the slope at appropriate vertical interval. The grass species should be selected as per the agro-climatic condition of the area, their adaptability and preference of farmers. The recommended grass barriers are Guinea grass, Napier, *Bhabar*, *Vetiver*, *Munj* and *Guatemala.*
5. **Conservation bench terracing (CBT):** The conservation bench terracing has been applied successfully to mildly sloping lands in arid, semi-arid and sub-humid regions for erosion control, water conservation and improvement of crop productivity. The CBT system consists of terrace ridge to impound run-off on a level bench and a donor watershed, which is left in its natural slope and produces run-off that spreads on the level bench. It is suitable for low rainfall condition, for taking assured crop on run-off recipient area. The ratio of run-off donor to run-off recipient area may vary from 1 : 1 to 3 : 1.

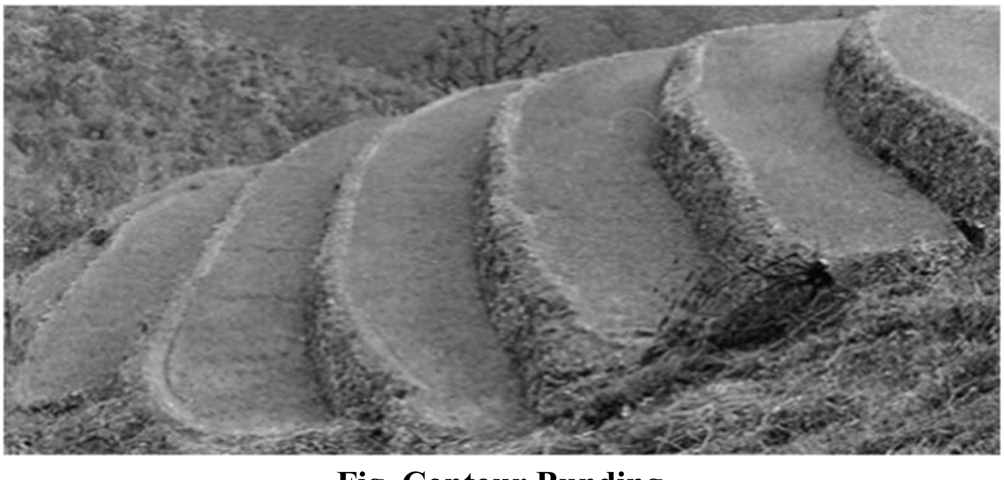


Fig. Contour Bunding

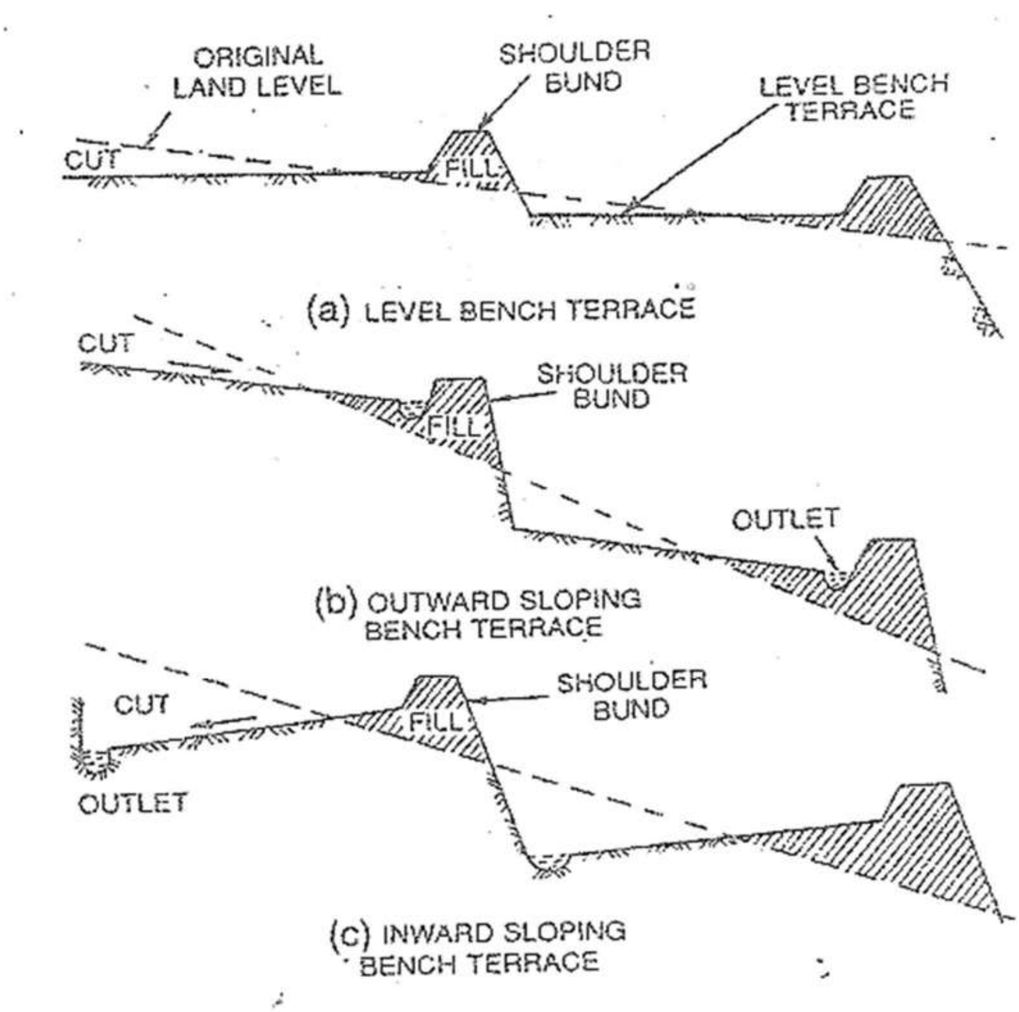


Fig. Bench Terracing

***In-situ* soil moisture conservation practices**

Storage of rainfall or rain water at the place where rainfall occurs for its effective usage is known as in situ moisture conservation. This can be achieved by different measures. Improving the soil surface conditions to increase infiltration of rainfall and reduction of runoff are the two basic requirements in dry lands. Hence land configuration determines the ease with which water can enter the soil. The different in situ moisture conservation practices which result in changed land configuration are as follows

A. **Ridges and furrows:**

   The field must be formed into ridges and furrows. Furrows of 30-45 cm width and 15-20 cm height are formed across the slope. The furrows guide runoff water safely when rainfall intensity is high and avoid water stagnation. They collect and store water when rainfall intensity is less. It is suitable for medium deep to deep black soils and deep red soils. It can be practiced in wide row spaced crops like cotton, maize, chillies, tomato etc. It is not suitable for shallow red soils, shallow black soils and sandy/ gravelly soils. It is not suitable for broadcast sown crops and for crops sown at closer row spacing less than 30 cm. Since furrows are formed usually before sowing, sowing by dibbling or planting alone is possible.

B. Tied ridging:

It is a modification of the above system of ridges and furrows wherein the ridges are connected or tied by a small bund at 2-3 m interval along the furrows to allow the rain water collection in the furrows which slowly percolated in to the soil profile

C. Broad bed furrows (BBF):

This practice has been recommended by ICRISAT for vertisols or black soils in high rainfall areas (> 750 mm). Here beds of 90-120cm width, 15 cm height and convenient length are formed, separated by furrows of 60 cm width and 15 cm depth. When runoff occurs, its velocity will be reduced by beds and infiltration opportunity time is increased. The furrows have a gradient of 0.6%. Crops are sown on the broad beds and excess water is drained through number of small furrows which may be connected to farm ponds. It can be formed by bullock drawn or tractor drawn implements. Bed former cum seed drill enables BBF formation and sowing simultaneously, thus reducing the delay between receipt rainfall and sowing. Broad bed furrow has many advantages over other methods as given below-

i. It helps in moisture storage
ii. Safely dispose off surplus surface runoff without causing erosion
iii. Provide better drainage facilities
iv. Facilitate dry seeding
v. It can accommodate a wide range of crop geometry i.e. close as well as wide row spacing.
vi. It is suitable for both sole cropping and intercropping systems.
vii. Sowing can be done with seed drills.

	
Ridges and Furrow	Tied Ridging

	
Broad Bed and Furrows	Compartmental Bunding

D. Dead furrows

At the time of sowing or immediately after sowing, deep furrows of 20 cm depth are formed at intervals of 6 to 8 rows of crops. No crop is raised in the furrow. The dead furrows can also be formed between two rows of the crop, before the start of heavy rains (Sep – Oct). It can be done with wooden plough mostly in red soils. The dead furrows increase the infiltration opportunity time

E. Compartmental bunding

Small bunds of 15 cm width and 15 cm height are formed in both directions to divide the field into small basins or compartments of square or rectangular shape of 6 x 6 m to 10 x 10 m size using bund former .They are useful for temporary impounding of rain water which facilitates high infiltration resulting in high moisture storage in the soil. Recommended for black soils with a slope of 0.5 to 1%. Maize, sunflower, sorghum perform well in this type of bunding.

	
Scooping	Contour Bunding

F. Scooping

Scooping the soil surface to form small depressions or basins help in retaining rain water on the surface for longer periods. They also reduce erosion by trapping eroding sediment. Studies have shown that runoff under this practice can be reduced by 50 % and soil loss by 3 to 8 t /ha.

G. Inter plot water harvesting

Water is drawn from part of a small catchment and used in lower portion for crop production. There may be 1: 1 cropped: catchment area or 1:2 catchment: cropped area.

H. Zingg terracing or conservation bench terracing

These are developed by A.W.Zingg, in USA. Zingg terracing is practiced in low to medium rainfall areas in black soils with contour bunds. It is a method of land shaping where lower one third portion of the land adjacent to the contour is levelled to spread to the runoff water coming from the remaining two third portion of the field .This rainfall multiplication technique ensures at least one good crop in one third area even in low rainfall years. Usually during medium rainfall years water intensive crops (like paddy) are cultivated in the levelled portion (receiving area) while dry crops are cultivated in the unlevelled (donor) area.

Types of antitranspirants:

1) **Stomatal Closing:** Phenyl mercuric acetate (PMA) and herbicides like atrazine in low concentration

2) **Film forming:** Silicones, Mobileaf, Hexadeconol.

3) **Reflectant:** Diatomaceous earth product (Celite), hydrated lime, calcium carbonate, magnesium, zinc sulphate, kaoline etc.

4) **Growth retardants:** Cycocel (CCC).

Task for students: Draw neat figures of all the *in-situ* soil and water conservation methods

Ex. No. 14

STUDY OF CROP MANAGEMENT PRACTICES FOR DRYLANDS OF BUNDELKHAND REGION

Table 1. Best management practices for Kharif crops in Bundelkhand region

Crops	Soils	Varieties	Sowing time and seed rate	Nutrient management	Water management	Weed management	Pest and disease management
Greengram (*Vigna radiata*)	Well drained loamy soil, however can be grown on heavy clay loam soils	Samrat, Meha, SML 668, HUM16, IPM 02-3, Sweta	Onset of monsoon, 15-20 kg ha^{-1}; 30cm x 10 cm spacing	20 kg ha^{-1}-N, 40 kg ha^{-1} P_2O_5, 20 kg ha^{-1}-S. (100 kg DAP and 120 kg gypsum recommended for nutrient management)	In *kharif* season it is grown without irrigation, however life saving irrigation can be given in case of long dry spell.	Pre-emergence application of Pendimethalin or fluchloralin @ 1 kg ha^{-1} + One hand weeding at about 25-30 DAS can suppress most of the weeds. Imazethapyr @ 0.05 kg a.i. ha^{-1}also found effective in post emergence application.	For sucking insects like Aphids, Jassids, Thrips apply monocrotophos (0.04%) or Dimethoate (0.03%). For pod borers, fenval (0.04%) or melathion 5% D is more effective. Yellow mosaic virus disease is common in Bundelkhand region so farmers are advised to use virus free seed after treating seed with carbendazim 50wp + thirum 75WP (1:1) at 2 g/kg seed. Foliar spray of 0.02% imidaclorpid at 30 and 45 DAS may be done for reducing spread of YMV.
Blackgram (*Vigna mungo*)	Well drained loamy soil, however can be grown on heavy clay loam soils	Uttara, Azad Urd 2, Shekhar 1, Shekhar 2, Narendra Urd 1	Onset of monsoon, 12-15 kg ha^{-1}; spacing 30cm x 10 cm	20 kg ha^{-1}-N, 40 kg ha^{-1} P_2O_5, 20 kg ha^{-1}-S. (100 kg DAP and 120 kg gypsum recomm-ended for nutrient management)	Hardy crop and grown without irrigation, however life saving irrigation can be given in case of long dry spell		
Sesame (*Sesamum indicum*)	Well drained soils. Red soils of Bundelkhand region is suitable for sesame crop.	T 78, Sekhar, Pragati, Tarun	Onset of monsoon, seed rate- 4-6 kg ha^{-1}; spacing 30cm x 15cm.	30 kg ha^{-1}-N, 20 kg ha^{-1} P_2O_5, 15 kg ha^{-1}-S.	Rainfed crop, however sensitive to drought as well as water logged conditions.	Weeds can be controlled by application of Pendimethalin @ 1 kg ha^{-1} + One hand weeding at about 25-30 DAS	Phyllody disease cause severe damage to sesame crop. To reduce vector population, application of phorate at 10 kg ha^{-1} as soil application or alternatively spray of dimethoate or monocrotophos (0.04%).

Groundnut (*Arachis hypogaea*)	Well drained, light coloured, loose and friable soil. Black soils (Kabar and Mar) not suitable for groundnut cultivation.	Amber, ICGS 5, ICGS 1, Prakash, GG 14, Girnar 2, Muktajyoti	Onset of monsoon, seed rate-100-120 kg ha^{-1} for bunch type varieties; spacing-30cm x 10cm.	25 kg ha^{-1}-N, 50 kg ha^{-1} P_2O_5, 40 kg ha^{-1}-K_2O. Band placement of gypsum @ 500 kg ha^{-1} at the time of pegging is essential for higher yields.	Predominantly rainfed crop, however in case of long dry spell life saving irrigation can be given at flowering or pegging stage.	Pre-plant incorporation of fluchloralin @ 1.5 kg a.i. ha^{-1} or pre-emergence application of pendimethalin @ 1.0 kg a.i. ha^{-1}.	For sucking pests apply dimethoate 0.05% solution. Application of carbofuron @ 1.0 kg a.i. ha^{-1} or Thimet 10G @ 20-25 kg a.i. ha^{-1} can reduce infestation of white grub. Seed treatment with bavistin @ 2.0g /kg seed or spray of bavistin 0.05% along with Diathene M 45 at 0.2% should be sprayed 2-3 times for controlling the early and late spot disease.
Maize (*Zea mays* L.)	Loamy sand to clay loam, Sensitive to water logging and salinity, requires well aerated, moist and weed free seed bed	PHEM-2, Malviya Hybrid Makka 2, Buland, Pro-Agro 4212, Bio-9681	Onset of monsoon, 20 kg ha^{-1}; spacing 60cm x 25cm	100 kg ha^{-1}-N, 40 kg ha^{-1} P_2O_5, 20 kg ha^{-1}-K_2O, 25 kg ha^{-1} $ZnSO_4.7H2O$.	Rainfed but late knee high, tasseling, 50% silking and dough stages are the critical stages for irrigation.	Pre-emergence application of simazine @ 1.0-1.5 kg ha^{-1}a.i. or Trifluralin @ 1.0 kg ha^{-1} as pre-plant incorpo-ration.	For control of maize borer, stubbles in the field should be burn and Trichocard (*Trichogramma chilonis*) should be released. Carbaryl 4% G.R. is found effective against maize stem borer. Seed should be treated with apron 35ws @ 2.5 g/kg seed to avoid infection of downy mildew.
Pigeonpea (*Cajanus cajan*)	Loamy soils, however can be grown on heavy clay loam soils,	Narendra Arhar 1, Amar, MAL 13 and	Last week of June or first week of July; 8-10 kg ha^{-1} for longer	20-25 kg ha^{-1}-N, 60-80 kg ha^{-1} P_2O_5, 20 kg ha^{-1}-S.	Branching, flowering and pod filling are the critical stages where moisture	The combination of pre emergence application of Pendimethalin @ 1 kg ha^{-1}+ one	For sucking insects like Aphids, Jassids, and Thrips apply monocrotophos (0.04%) or Dimethoate (0.03%).

	saline and alkali soils	BSMR 736	duration, 10-12 kg ha^{-1} for medium and 12-15 kg ha^{-1} for short duration varieties; Spacing 40-60cm x 10-15cm (Short and Medium duration varieties) and 60-120cm x 10-20 cm (Long duration varieties)		stress conditions cause adverse effects on growth and development.	hand weeding is observed best method to weed control. Imazethapyr @ 0.05 kg a.i. ha^{-1} also found effective as post emergence application.	For pod borers, fenval (0.04%) or melathion 5% D is more effective. Spray of metasystox (0.1%) controls the mite which spread sterility mosaic virus in pigeon pea.
Sorghum (*Sorghum bicolor*)	Clay loam or loam texture with good water reten-tion capacity. Most of the Bundelkhand soils are suitable for sorghum cultivation. Tolerant to water stress conditions.	Bundela, CSV 10, CSV 11, CSH 9, CSH 16, SPV 462	Onset of the monsoon, timely sowing essential for escape from shoot fly. Seed rate- 10-12 kg ha^{-1}; Spacing 45cm x 15cm.	50 kg ha^{-1}-N, 40 kg ha^{-1} P_2O_5, 20 kg ha^{-1}- K_2O.	Drought tolerant and can be grown successfully as rainfed crop in Bundelkhand region.	Pre-emergence application of atrazine @ 0.75-1.0 kg ha^{-1}a.i. or Pendimethalin @ 1.0 kg ha^{-1}. 0.5 kg a.i. ha^{-1} 2,4-DEE for control of broad leaf weeds.	For control of shoot fly, crop should be sown timely and seed should be treated with imidaclorpid70 WS @ 10-15 g a.i./kg seed.

Table 2. Best management practices for Rabi crops in Bundelkhand region

Crops	Soils	Varieties	Sowing time and seed rate	Nutrient management	Water management	Weed management	Pest and disease management
Wheat (*Triticum aestivum*)	Wheat can be grown on all types of soils except on water-logged soils. Medium loam, well drained soils are suitable for its cultivation.	Early and timely sown HW 2004, HI 1500, HI 1531, Raj 1555, Lok 1, GW 273 Late sown- GW 173 MP 4010 HD 2932 (Pusa wheat-111), Vidisha	Early-15-30 October, Timely-5-25 November, Late-25 Nov.- 15 Dec., Seed rate- 100kg ha^{-1} for irrigated conditions and 150 kg ha^{-1} for rainfed conditions; Spacing- 22.5cmx5 cm.	Irrigated- 120 kg ha^{-1}-N (Three split), 60 kg ha^{-1} P_2O_5, 40 kg ha^{-1}- K_2O. Rainfed- 80 kg ha^{-1}-N (Two split), 40 kg ha^{-1} P_2O_5, 40 kg ha^{-1}- K_2O.	There are six critical stages for irrigation but depending upon the water resources available with the farmers irrigation can be given as 01 irrigation-at CRI (21 DAS), 02 irrigation-CRI and Flowering (F) (85 DAS), 03 irrigation-CRI, late jointing (LJ) (60 DAS) and milk (M) (95 DAS), 04 irrigation-CRI, Late tillering (LT) (42 DAS), flowering and milk stage, 05 irrigation- CRI, LT, LJ, F and M, 06 irrigation- CRI+LT+LJ+F+ M+Dough	Pendimethalin 1.5 litres/ha as pre-emergence and isoproturon @ 0.75 kg a.i. ha^{-1}+2,4-D @ 0.5kg ha^{-1} as post emergence (25-30 DAS) found effective.	For termite control treat the seed with chlorpyriphos 20 EC @ 4ml/kg seed or mix 2 litres chlorpyriphos 20 EC with 25 kg sand ha^{-1}. Smut can be controlled by seed treatment with vitavex or raxil @ 1.5g ka^{-1} seed
Barley (*Hordeum vulgare*)	Barley thrives best on well drained loam soil but can be successfully raised even on poor sandy soils. Barley requires very	RD-2508, RD-2552, K-125, K-603	Last week of October to first week of November; Seed rate- 100 kg ha^{-1} (irrigated) conditions and 125 kg	Irrigated- 60 kg ha^{-1}-N, 40 kg ha^{-1} P_2O_5, 30 kg ha^{-1}- K_2O. Rainfed- 40 kg ha^{-1}-N, 30 kg ha^{-1}	Drought tolerant having very limited water requirement. However for higher yield, irrigation can be given at 30-35 DAS (Active tillering) and at 60-65 DAS		

	less water than wheat.		ha^{-1} (rainfed) conditions; Spacing-22.5cmx5cm.	P_2O_5, 20 kg ha^{-1}- K2O.	(Booting).		
Chickpea (*Cicer arietinum*)	It requires a loose and well aerated seedbed. Light soils, mostly sandy loams are preferred in Bundelkhand Region.	DCP 92-3, JG 16, KWR 108 & KGD 1168, GG-1, Pragati	last week of September to mid of October under rainfed condition; Seed rate- 75-80 kg ha^{-1}; Spacing- 30cmx10cm.	20 kg ha^{-1}-N, 40 kg ha^{-1} P_2O_5, 20 kg ha^{-1}-S, 25 kg ha^{-1} $ZnSO_4$. $7H_2O$.	Drought tolerant. For higher yield one irrigation can be given at pre flowering stage.	Pendimethalin 1.5 litres/ha as pre-emergence should be apply to control weeds.	Wilt resistant varieties are: JG 16, Vijay, JAKI 9218, JG 315, JG 74 and JGK-1 should be preferred in areas where wilt is a severe problem. Deep sowing, seed treatment with bavistin or Trichoderma and crop rotation reduces the wilt incidence. Spray of NSKE 5% / NPV 250 LE/Indoxacarb 500 ml/ha for controlling the Pod borer.
Lentil (*Lens culinaris*)	Lentil can be grown on all types of soils except the water logged soils	Jl3, DPL 62 and IPL406, Narendra masoor 100, L4076	2nd and 3rd week of October best time for sowing; Seed rate- 30 to 40 kg ha^{-1} (small seeds) and 50 to 60 kg seed ha^{-1} (large seed); Spacing- 30cm x 5cm.		Like chickpea, lentil is also taken without irrigation. However, one irrigation at the time of flower initiation/ pod formation stage increases the yield.		For wilt control measures are use of wilt resistant varieties, seed treatment before sowing with fungicides and crop rotation up to three years. Ploughing of field during summer season also help in reducing the occurrence of wilt disease.
Field Pea (*Pisum sativum*)	Field Pea can be grown on all types of soils except the	Prakash, Adarsh, Vikas, Ambika, Shikha,	Mid of October to mid of November; Seed rate-		Generally 2-3 irrigation are required; first at flower initiation stage & Second	Generally 2 to 3 weedings are necessary to keep the field free from weeds.	Powdery mildew is most severe disease so resistant varieties like Rachana, Hans, P 185, P 388 can be sown. Use of fungicide in

	water logged soils.	Indra, Aparna, Prakash	80 to 100 kg ha^{-1}; Spacing- 30cmx10cm.		at grain filling stage. Soil moisture deficit reduces growth and also hampers nodulation.	Pendimethalin 1.0kg ha^{-1} as pre-emergence	seed treatment and foliar spray reduces its incidence.
Rapeseed & Mustard (*Brassica* spp.)	Rapeseed-mustard crops are grown on sandy loam and clay-loam soils. Requires fine seed bed	Early sown- Kranti, NDRE-4, Pusa Mahak, Pusa Agrani, Pusa mustard 25 Timely sown- NRCHB 506 (Hybrid), DMH 1 (Hybrid), Coral PAC 432 (Hybrid), Maya, Vasundhara, Rohini, Basanti, Urvashi, JM 1, JM 2.	2[nd] and 3[rd] week of October best time for sowing; Seed rate- 4-6 kg ha^{-1}; Spacing- 30cm x 10cm.	40 kg ha^{-1}-N, 30 kg ha^{-1} P_2O_5, 20 kg ha^{-1}-S.	If water is available, two irrigations, first just before flowering and the second at the pod filling stage. In case of one irrigation, it may be provided at initiation of flowering.	Intercultural operations should be done 15-25 days after sowing of the crop. Pre sowing incorporation of 1 kg ha^{-1}a.i. fluchloralin (45 EC) or pre emergence application of Pendimethalin (30 EC) chemically controls the weeds.	Use Oxydemeton methyl 25 EC or Dimethoate 30 EC @ 625, 850 and 1000ml dissolved in 625, 850 and 1000 litres of water ha^{-1}, respectively in 3 sprays at 15 days interval.

Note-Seed of pulses should be treated with their respective *Rhizobium* culture @ 200g packet/10 kg seed.

Source: Singh, M., K.B. Sridhar, Dhiraj Kumar, R.K. Tewari, Inder Dev, Asha Ram, A.R. Uthappa, Veeresh Kumar, Ramesh Singh and R.P. Dwivedi (2018). Options and Strategies for Farmers' Income Enhancement in Bundelkhand Region of Central India. Technical Bulletin No.2/2018. ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi, India.

Ex. No. 15

STUDIES ON WATERSHED, ITS CHARACTERISTICS AND DELINEATION OF MODEL WATERSHED

Most of the arid and semiarid regions have been neglected for years together. It is only in recent years little attention has been paid to the problems of these areas. The regions have concentration of eroded and degraded natural resources. Loss of vegetative cover followed by soil degradation through various forms of erosion is seen every whereas a result of which soils are thirsty in terms of water as well as hungry in terms of soil nutrients. Most of these regions have predominantly live stock centered farming system. Loss of biomass for animals not only reduces animal productivity but subsequent intense grazing pressure on already eroded lands. Growing population pressure higher demands of feed and fodder coupled with impact of rapidly changing socio-economic conditions have added fuel to the fire. The contour bunding or terracing on individual holding or groups of farms result in marginal benefits as they are done ignoring to what happens to other area, which are influencing the hydrologic characteristic. Such sporadic conditions generally fail to attract the farmers as they do not yield benefit commensuration with the effort and investment made. Thus, for maximizing the advantages, all the developmental activities should be undertaken in a comprehensive manner on watershed basis.

Watershed is the area above a given point on a stream that contributes water to flow at that point. **Catchments basin and drainage** are synonymous with it. It include all the practices applied to the land that are effective in reducing run-off, erosion, increasing the amount of surface storage, rate of infiltration and water holding capacity of the soil.

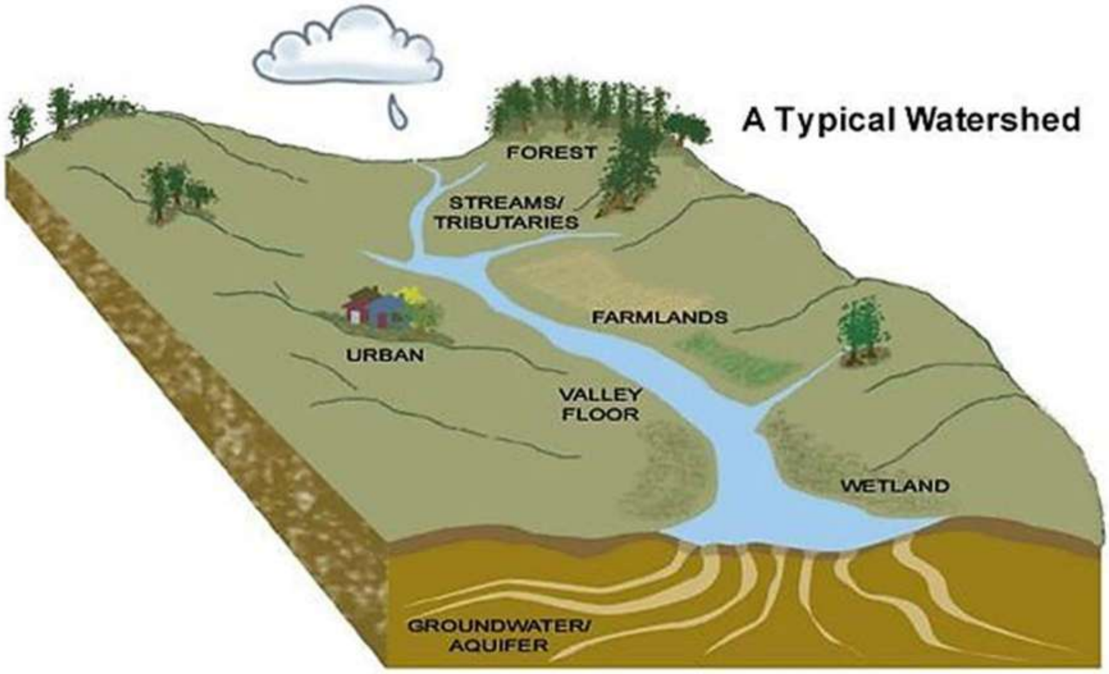
Definition:

Watershed is a drainage area on and surface from which runoff from precipitation reach a particular point called common outlet. In other words it is the land surface bounded by a divide, which contribute run off to common point.

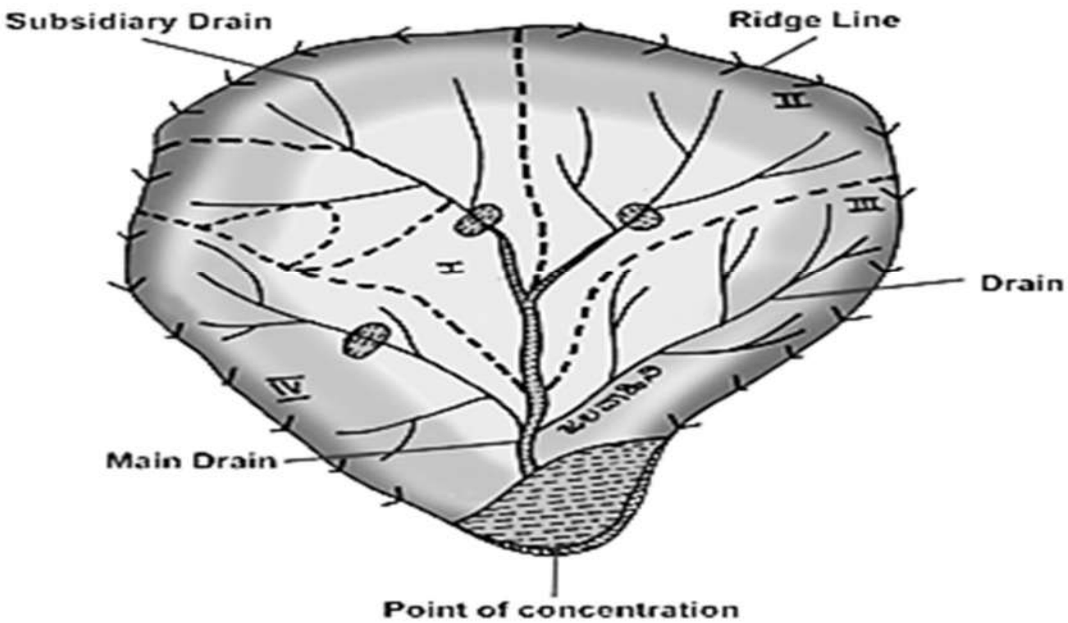
Concept of watershed Management:

The concept of watershed development and management lies in identifying the potential of different pockets of watershed for agriculture production. A watershed should be treated as an acceptable unit of planning for optimum use and conservation of natural resources like soil and water. As the entire process of agricultural development depends on status of water resources. Watershed with distinct hydrological boundary is considered ideal for planning developmental programmes. On watershed basis in conjunction with basic soil and water conservation measures.

Watershed management programme in dry lands is aimed at optimizing the integrated use of natural resource like soil water, vegetation for providing an answer to alleviate drought, moderate floods, prevent soil erosion, improve water availability and increase food, fodder, fuel and fiber on stained basis.



WATERSHED



Principles of watershed Management:

Following are the principles of watershed management based on resources management, resources generation and resources utilization.

1. Utilizing the land according to its capability.
2. Protecting top profile of soil.
3. Conserving as much rain water as possible at the place where it falls.
4. Minimizing silting of tanks, reservoirs, and lower fertile lands.

5. Protecting vegetative cover thought the year.
6. Draining out excesses water with a safe velocity and diverting it to storage ponds, and store it for future use.
7. Avoiding gully formation and putting checks at suitable interval to control soil erosion and recharge ground water.
8. Increasing cropping intensity through intercropping and sequence cropping.
9. Maximizing productivity for unit time per unit water.
10. Safe utilization of marginal lands through alternate land use system.
11. Maximizing farm income through agricultural activities such as dairy, poultry, sheep and goat farming.
12. Improving infrastructure facilities for storage, transport, and agriculture marketing.
13. Setting up of small-scale agro-industries.
14. Improving socio-economic status of farmers.

Objectives of Watershed Management:

1. Recognition of watershed as a unit of development and efficient use of land according
   to their land capability.
2. Flood control through small multipurpose reservoirs and other water storage structure at the hard water of streams and in problem areas.
3. Adequate water supply for domestic, agricultural and industrial needs.
4. Abetment of organic, inorganic and soil pollution.
5. Efficient use of natural resources for improving agriculture and allied occupation so as to improve socio-economic condition of the beneficiaries.
6. Expansion of recreation facilities such as picnic and camping sites.

Classification of watershed is done on basis of area:

1. Macro watershed: 400 to 2000 ha.
2. Micro watershed: Less than 400 ha.

Agricultural watersheds:

i) Sub watershed: 10,000 to 50,000 ha.
ii)Multiwatershed : 1000 to 10,000 ha.
iii) Micro watershed: 100 to 1000 ha.
iv) Miniwatershed: 1 to 100 ha.

Components of Watershed Management

The following components must receive attention in any watershed development project

1. Soil and water conservation.
2. Water harvesting and recycling for protective irrigation.
3. Crop management

4. Alternate level use system.
5. Ground water recharge and development.

Efficient us of available water through proper field layouts, lands shaping, leveling and lining of water sources and lifesaving irrigation. Development of livestock, Poultry, and other associated activities.

Crucial component of watershed development project is the organization land use problems can only be solved in close association with landowner. Such local people should be involved in the project.

The size of watershed should be 300 to 500 ha. At micro level and a cluster of about 10 such watershed could be managed by a single organization unit.

1. Soil and Water Conservation

These measures are aimed at improving soil moisture availability and surface water availability for supplemental irrigation. Conservation measures in arable lands can be broadly divided in to three categories: permanent, semi-permanent and temporary.

Permanent measures: These measures are for improving relief, physiography and drainage features of watershed aimed at controlling soil erosion, regulating surface runoff and reducing peak flow rates. Bunds, terraces and waterways are the permanent measures in watershed management project.

Semi-permanent measures: These are usually inter-bund treatments in conventionally bunded area. They are adopted to minimize the velocity of overland flow. Such measures may lost 2 to 5 years.

Temporary measures: These are simple treatments for *in situ* moisture conservation and needs remade or renovation every year. Simple practices like contour farming, compartmental bunding, broad bed and furrows, dead furrows and mulching have gained wide acceptance in the recent past.

A. Hardware components:

Hardware components are generally cost effective in nature; they are usually financed by government. These includes all mechanical methods of soil and water conservation

1. Foundation treatment for land and water resources mainly in agricultural land such as diversion bunds, contour and graded bunds, check dams, and grass water ways.
2. Water storage structure including Nalla Bunds, gully plugs ponds percolation tanks, open wells, etc.,
3. Alternate land uses afforestation, and plantation fodder, fuel trees and pasture development.

B. Software Components:

These are simple treatments for *in situ* moisture conservation and needs remade or renovation every year. Components include improved crops and cropping systems. This also includes contingency cropping to meet the weather aberrations. These may include use of plant protection measures improved implements etc. These includes all cultural methods of soil and water conservation

2. **Water harvesting**

Farm ponds, check dains, percolation wells and minor tanks for water harvesting.. These structures are effective not only for reducing erosion and storing excess water during peak periods of monsoon but also for improving ground water table and recharging the downstream wells.

3. **Crop Management**

Location specific package of practices for dryland crops have been developed by dryland research centers and state agricultural universities for all the crops and cropping systems covering several aspects.

1. Crops and varieties to suit length of cropping season,
2. Optimum seeding time,
3. Fertilizer schedules and balanced use of plant nutrients for crops and cropping systems identified.
4. Weed management and package of practices for aberrant weather, and
5. Contingent crop planning.

4. **Alternate land use system**

Most of uplands in watershed area degraded to very low productive levels. Apart from being uneconomical arable crops, such as causing serious imbalance in the ecosystem. For such lands, alternate land use system, other than cropping would be desirable. Such land use system can lead to stability in production along with safety in environment.

- Bring marginal and sub-marginal lands under cultivation.
- Select alternate efficient land use system than arable cropping.
- Encouraging tree and grass components.
- Helps in generating off season employment.
- Helps in utilizing off season rainfall.

Steps in Watershed Management

Soil and hydrologic factors assume significance since the elements involved largely determine as to whether the desired programme can be carried out or not. The portion of hydraulic cycle from the time water is received on land surface until it leaves the area as stream flow or is back in the atmosphere through evapotranspiration is the central core of control in watershed management.

Surface runoff depends on intensity, duration and amount of rainfall. Topography of land determines direction of runoff. Soil characters like intake capacity, moisture retentivity etc. influence movement of water in the soil. Runoff is influenced by length and degree of slope, vegetative cover etc. All these factors influencing water movement cannot be changed through management. However, some of these can be modified to achieve the aims of watershed management.

Watershed Delineation:-

- Creating a boundary that represents the contributing area for a particular control point or outlet
- Used to define boundaries of the study area, and/or to divide the study area into sub-areas
- All **watershed delineation** means is that you're drawing lines on a map to identify a **watershed's** boundaries. These are typically drawn on topographic maps using information from contour lines. Contour lines are lines of equal elevation, so any point along a given contour line is the same elevation.
- **Watershed** boundaries are defined by topographic divides and **delineate** areas where surface-water runoff drains into a common surface-water body, such as a lake or section of a stream.
- Delineated watersheds are required for HSPF (Hydrological Simulation Program – FORTRAN) modelling and for BASINS watershed characterization reports
- So we can characterize and investigate what is going on in one portion of the study area versus another.
- Delineation is part of the process known as watershed segmentation, i.e., dividing the watershed into discrete land and channel segments to analyse watershed behaviour

The delineation of priority area can be performed to some extent by reconnaissance survey and study of topo-sheets. However, these techniques are slow and also not providing very accurate result. Demarcation of priority areas can also be done in better way by using the arial photograph, the contour maps of 1:60,000 scale are most suitable, but the photographs of larger scale such as 1:15,000 can also be sued for the purpose.

The demarcation of priority areas should be accomplished on watershed basis, because a comprehensive watershed management approach is essential for sue of proper soils conservation measures. For demarcation priorities areas on watershed basis, the preparation of framework of watershed to be delineated should be from 10,000 to 20,000 ha, because for small watersheds the formulation of soil conservation plans and their execution over a reasonable period is practically possible and easy, also.

The steps for demarcation of small size watershed are described as under:

1. Divide the entire watershed into different sub-watersheds considering important tributaries. The size of sub-watered should be few lakh hectares. Use suitable scale for delineation. Normally, 1:1 million and 1:250,000 scales are followed.
2. Again, divide each sub-watershed into small following distinct tributaries and streams passing through the respective sub-watersheds . The size of small watersheds should be in the range of 50,000 to 1,00000 ha. Delineate these small watersheds using the scale 1:50,000. and superimpose the delineated sub-watershed in step (1) on the base map of the area.

3. Further sub-watershed if there are large number of small watershed a (as obtained in step 2) in the size ranging from 10,000 to 20,000 ha.

In the watershed if there are large number of small streams, that drain the runoff directly into the main stream, then demarcation of small size watershed is difficult. For such condition the demarcation is carried out by combining all the streams into sub-watershed, small watershed etc as per size indicated earlier. This should be started from the downstream end and proceeded to upstream side.

Task for students: Draw the theme map of watershed for Agriculture college farm area of BUAT Banda

Ex. No. 16

STUDIES ON FIELD DEMONSTRATION ON SOIL AND MOISTURE CONSERVATION MEASURES

Soil and water are important resources of agriculture. Soil and water conservation is the most important contributing factor in Rainfed farming for better economic production of crops. This can be achieved by adopting agronomical and mechanical measures.

Sr. No.	**Name of soil and water conservation measures**	**Remarks**
A	**Agronomic/Cultural Practices**	
1	Mulching –Organic- crop residue @ 5 t/ha	
	No mulch	
2	Contour cultivation	
	No Contour cultivation	
B	**Mechanical practices**	
1	Contour bonding	
	No. Contour bonding	
2	Compartmental bunding	
	No. Compartmental bunding	
3	Broad bed furrow (BBF)	
	No. Broad bed furrow (BBF)	
4	Continuous contour trench (CCT)	
	No. Continuous contour trench (CCT)	

Ex. No. 17

STUDIES ON FIELD DEMONSTRATION ON WATER HARVESTING STUDIES

Method of water harvesting

I) In areas with 50 to 80 mm annual rainfall	**II) Arid Regions (Annual Rainfall < 500 mm)**	**III) Semi- Arid Regions (Annual Rainfall 500 – 750 mm)**
1. Land alteration	1. Run-off farming	1. Dug wells
2. Chemical treatment	2. Inter plot water harvesting-	2. Tanks
3. Surface cover	3. Micro- catchment	3. farm ponds
	4. Water spreading	4. percolation tanks-
		5. Inter row water harvesting
		6. Broad beds and furrow and farm ponds

Sr. No.	**Name of harvesting structure**	**Remarks**

Ex. No. 18

VISIT TO RAINFED RESEARCH STATION/ WATERSHED AREA

Name of Rainfed research station/ watershed visited:

Background information of research station / watershed area:

Observations of visit:

1. Total Area :-
2. Cultivable area
3. Uncultivable area :
4. Cropping system:
5. Source of irrigation:
6. Measures of soil and water conservation adopted: