RAINFED AGRICULTURE & WATERSHED MANAGEMENT




COURSE TITLE:

RAINFED AGRICULTURE AND WATERSHED MANAGEMENT

COURSE NO.: AGRO-235 **CREDITS: (1+1) =2**

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THEORY NOTES

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Teaching Schedule

Lecture	Topic	Weightage (%)
1	Rainfed agriculture: Introduction, types, History of rainfed agriculture and watershed in India	8
2-3	Problems and prospects of rainfed agriculture in India	8
4	Soil and climatic conditions prevalent in rainfed areas	10
5	Soil and water conservation techniques	10
6-7	Drought: types, effect of water deficit on physio- morphological characteristics of the plants	10
8-9	Crop adaptation and mitigation to drought	8
10-11	Water harvesting: importance, its techniques, Efficient utilization of water through soil and crop management practices	10
12	Management of crops in rainfed areas	8
13-14	Contingent crop planning for aberrant weather conditions	10
15	Concept, objective, principles and components of watershed management	10
16	Factors affecting watershed management	8
	Total	**100**

Suggested Readings:

1) Sustainable Development of Dryland Agriculture in India – R. P Singh
2) Dry Farming Technology in India – P. Rangaswamy
3) Dryland resources and Technology – Vol. 8 L.L Somani, K.W. Kaushal
4) Physiological Aspect of Dryland Farming – U.S Gupta
5) Principles of Agronomy S.R. Reddy
6) Dryland Technology – M.L. Jat, S.R. Bhakar, S.K. Shrma , A. K. Kothri
7) Climate, Weather and Crops in India – D. Lenka

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THEORY NOTES
Course No. AGRO-235
Course Title: - Rainfed Agriculture and Watershed Management

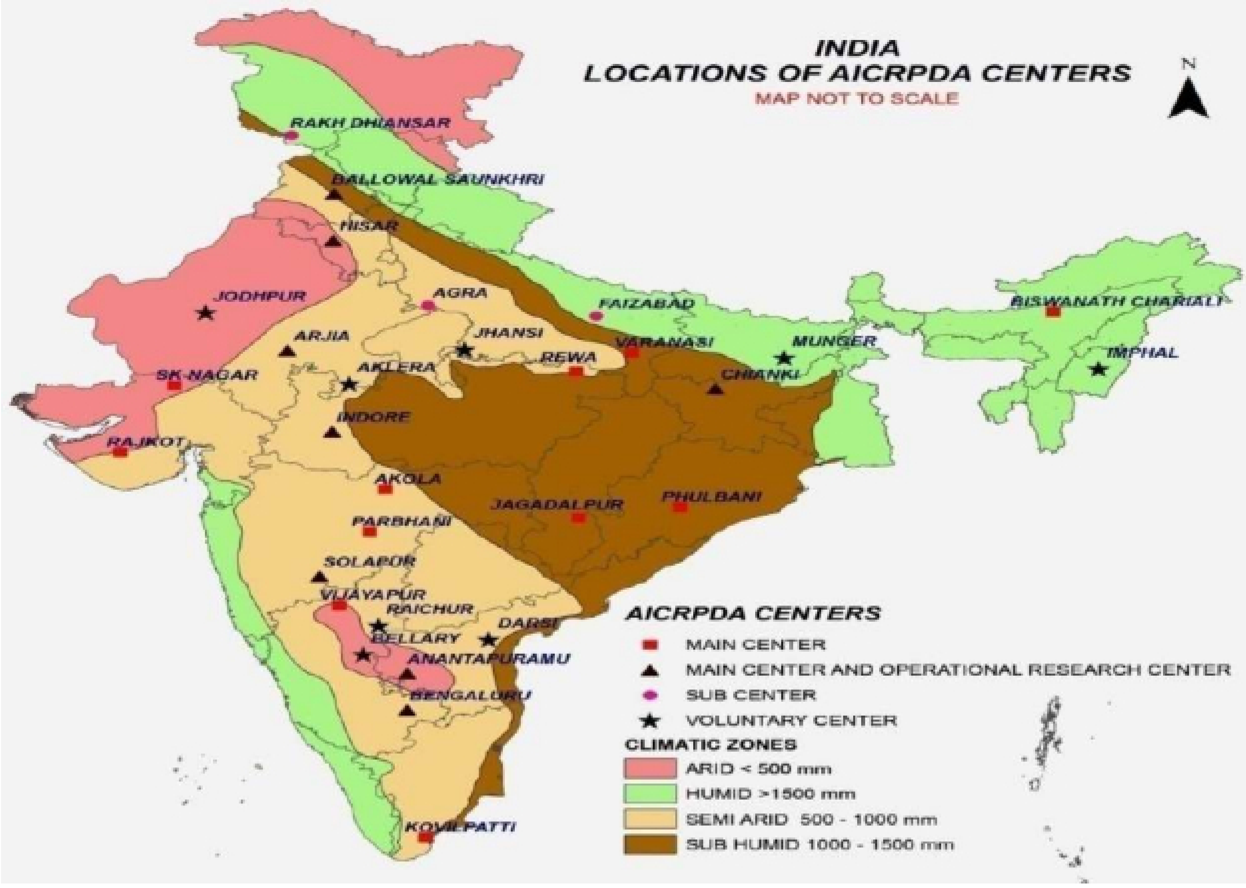
INTRODUCTION

Indian agriculture is 'a gamble in the monsoon' even today. So, water has been prioritized to be the most crucial resource for sustainable development of agriculture. The life of mankind and almost all the flora and fauna on the earth depends on the availability of fresh water resources. It is an extremely important component of biological systems. The most of the plant cells and tissues contain 80-90 per cent water by weight. Plant water status influences all the physiological processes of plants directly or indirectly. Highly variable global distribution of annual average rainfall of about 1000 mm on the earth surface is responsible for the disparities in agriculture production and socio-economic conditions. Fifty five per cent or more than one-half of the total land surfaces of the earth, receives an annual precipitation of less than 500 mm and must be reclaimed, if at all by dry farming practices. Area with 500-750 mm rainfall, which accounts for 10 per cent of the total land area, also need dry farming measures for successful crop production

In India also, distribution of the annual average rainfall of about 1200 mm, is highly variable, irregular and undependable with wide spread variations among various meteorological sub-divisions in terms of distribution and amount. The spatial distribution of rainfall varies from 100mm/annum in Rajasthan to about 11000 mm/annum in Cherrapunji in Meghalaya. Agriculture uses almost 85 per cent of the total water available in the country. Of the total geographical and net cultivated area about 92 and 33 million hectares receive less than 750 mm rainfall annually respectively

Table . Distribution of dryland area in different rainfall zones in India.

Mean annual rainfall (mm)	Climate zone	Dry land area (million ha)
<500	Arid	10.9
500-750	Dry semi-arid	22.2
750-1000	Wet semi-arid	21.2
1000-1250	Sub-humid	19.6
>1250	Humid	27.7



Agriculture continues to be mainstay of the Indian economy. It contributes 25 per cent of the national gross product. In this contribution, rainfed lands in India are important today and will continue to be so in future. Currently, about 70 per cent of agriculture in India is rainfed. This area contributes nearly 44 per cent to food production and supports 40 per cent of the human and 60 per cent of the livestock population. Even if the entire irrigation potential of the country is used, still about half of the cultivated land will remain rainfed. About 30 per cent of the country (109 million ha) is drought prone and suffers with critical water shortages. Rainfed agro-ecosystem covers about 90 million ha of net cultivated area, which is distributed unequally among different states. In Assam, Gujarat, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra and Rajasthan more than 70 per cent of the net cultivated area is rainfed. Besides uncertainties in rainwater availability, the swings in the onset, continuity and withdrawal pattern of monsoon make crop production in rainfed areas a risky proposition. The coefficient of variation in the monsoon rainfall in areas located in the rainfall zones of < 500 mm, 500 -700 mm, 700-1000 mm and > 1000 mm is in the range of 50-55, 40-50, 30-40 and 20-30 per cent, respectively.

Water is the most scarce resource in rainfed agriculture. Inefficient use of this scarce resource leads to inefficiency of all other inputs. In water resource management, the focus is not merely on development of new water resources but also on efficient utilization of already developed ones particularly based on indigenous systems. The precipitation reaching the earth surface may be intercepted by vegetation, may infiltrate into the ground, may flow over land surface as run -off or may evaporate. Evaporation may occur over the land surface or free water or from the leaves of the plant through transpiration. Soil acts as a reservoir for the water that enters the soil. Water in the soil is always in transitory storage. Rainfed areas can be made productive and profitable by adopting improved technologies for rainwater conservation and harvesting and commensurate agricultural production technologies. The fundamental problems of dry farming are:-

- Storage in the soil of a small annual rainfall;
- Retention of the moisture in the soil until it is needed by the plants;
- Prevention of direct evaporation of soil moisture during the growing season;
- Regulation of the amount of water drawn from the soil by plants;
- Choice of crops capable of growth under moisture stress conditions and
- Crop management for proper utilization of stored soil moisture.

The relation of crops to the prevailing conditions of arid lands offers another group of important dry farm problems. Some plants are drought resistant and some are drought tolerant. Some attain maturity in short duration and are suitable for dry farming. Some crops and varieties have deep root system or waxy layer, which aid in their survival under moisture stress. After the selection of crops, skill and knowledge are needed in the proper seeding, tillage, nutrient management, plant population, weed control and mid-season correction for efficient use of conserved moisture.

Dry lands: Areas which receive an annual rainfall of 750 mm or less and there is no irrigation facility for raising crops.

Rainfed Agriculture: - Growing or cultivation of crops entirely on rainfall without irrigation

Rainfed Agriculture / Dry land Agriculture: Scientific management of soil and crops under rainfed condition without irrigation is called dry land agriculture.

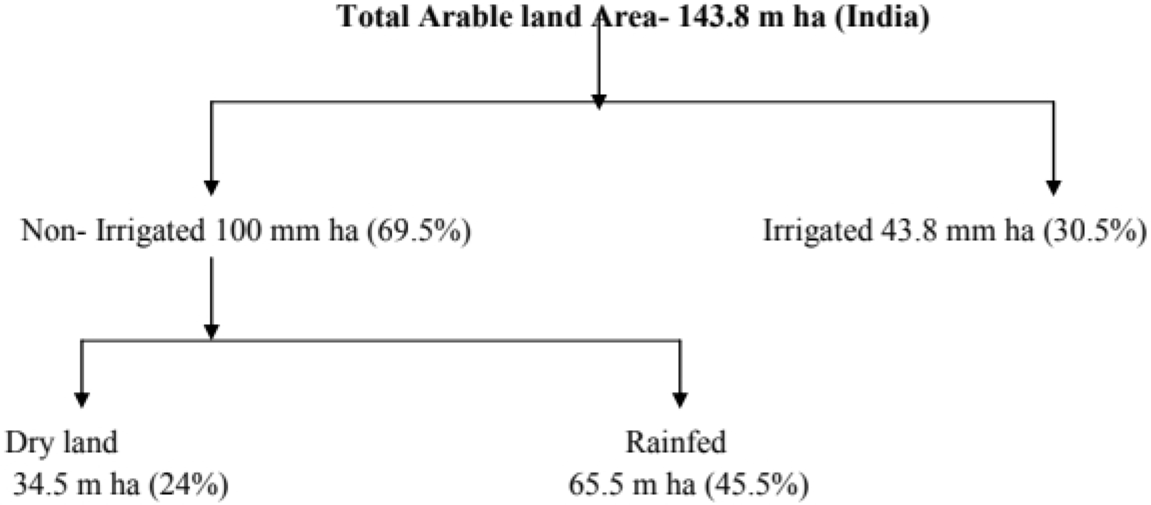
Dry land crops: It refers to all such crops which are drought resistant and can complete their life cycle without irrigation in areas receives an annual rainfall less than 750 mm.

Drought: It is an condition of insufficient moisture supply to the plants under which they fail to develop and mature properly. If may be caused by soil, atmosphere or both.

Dry farming : In the country with low and precarious rainfall two types agricultures are usually met, one crop production on aerable farming land other animal husbandry, including management of grazing areas.

About 100 m.ha (69.5%) of tatal cropped area falls under Rainfed and Dryland farming. Dry farming areas as per the 9^{th} plan one those area receiving rainfall less the 750 mm year and limited irrigation facility is available. Areas which receiving the mean rainfall less than 375 mm per year are considered as absolute arid and desert areas and require special technology treatment. About 128 district in the country falls under dry framings as defined above. Out of these, 25 district from the desert land of Rajasthan Sourashtra and rain shadow regions of Maharashtra and Karnataka belong to very height intensity dry farming areas.

Total Arable land Area- 143.8 m ha (India)



Area under dry land is likely to a change according to definition and irrigation facilities developed from time to time. Areas receiving annual rainfall between lees than 750 mm is known as dry farming tracts zones.

There are about 105 districts under this category but 18 of these districts have good irrigation facilities. Therefore dry farming tract comprises 87 districts spread over Andrapradesh, Gujart, Haryana, Punjab, Karnataka, MP, Maharashtra, Rajastan, Tamilnadu and Uttar Pradesh

Even after the **utilisation** of all our water resources for irrigation, about half of the **cultivated area will** remain rainfed. As there is hardly any scope for increasing the area under cultivation, it is really a *colossal task* for meeting the future food needs. It is against this background that the role of *dryland* agriculture gained importance.

Very often, the words dry farming, dryland famming and rainfed farming are used **synonymously** to indicate similar farming situation. Clearly, all the three exclude irrigation.

- Dryland agriculture means cultivation of crop entirely under rainfed conditions.
- In such areas crop production becomes relatively difficult as it mainly depend upon the intensity and frequency of rainfall.

CLASSIFICATION OF FARMING BASED ON ANNUAL AVERAGE RAINFALL AND LENGTH OF GROWING PERIOD

1. **Dry farming:-** is cultivation of crops in regions with annual rainfall less than 750 mm, crop failure is most common due to prolonged dry spells during the crop period. These are arid region with a growing season (period of adequate soil moisture) less than 75 days. Moisture conservation practices are necessary for crop production.
2. **Dryland farming:-** is cultivation of crops in regions with annual rainfall more than **750** *m*. Inspite of prolonged dry spells, crop failure is relatively less frequent. These are semi-**arid** ***tracts with a growing period between 75 and 120 days.***
3. ***Rainfed farming:-*** is crop production in regions with annual rainfall more than 1,150 mm. Crops are not subjected to soil moisture stress during the crop period. Emphasis is often on disposal of excess water. These are humid regions with growing period more than 120 days.

In dry farming and dryland farming, emphasis is on soil and water conservation, sustainable crop *yields* and limited fertiliser use according to soil moisture availability. In rainfed agriculture, emphasis is on disposal of excess water, maximum crop yield, high levels of input and control of water erosion.

Table: Rain dependent farming (Classification based on annual average rainfall and length of growing period)

Aspects	**1. Dry farming**	**2. Dryland farming**	**3. Rainfed farming**
Annual rainfall	< 750 mm	750-1150 mm	> 1150 mm
Crop failure	Common	Less frequent	No
Region	Arid	Semiarid	Humid
Growing period	< 75 days	75-120 days	> 120 days
Moisture conservation	Required	Necessary + Drainage	Disposal of excess water
Emphasis/constrains	Soil and water conservation		Disposal of excess water
Crop yields	Sustainable		Maximum
Input use	Limited		High levels
Wind and water erosion constraints	Both		Water
Cropping System	Single	Single/ Intercrop	Intercrop/ double crop

United Nations Economic and Social Commission for Asia and the Pacific distinguished dryland agriculture mainly into two categories: dryland and rainfed farming. The distinguishing features of these two types of farming are given below.

Table : Dry land Vs Rainfed farming.

Constituents	**Dryland farming**	**Rainfed farming**
1. Rainfall (mm)	< 750mm	>750 mm
2. Moisture	Shortage	Enough / Sufficient

3. Growing season	<200 days	>200 days
4. Growing regions	Arid and Semiarid & up lands of sub humid & humid regions.	Humid and slub humid regions.
5. Cropping system	Single crop or intercropping	Intercropping or double cropping.
6. Constraints	Wind and water erosion	Water errosion.

CHARACTERISTICS OF DRY LAND AGRICULTURE / RAINFED AREA

1. Uncertain and limited annual rainfall:- The crops very often suffer from aberrant weather like delayed onset of monsoon, long gap in rainfall and early stoppage of rains.

2. Extensive climatic hazards: - This area has to face either flood, water logging or drought, The crops suffer badly from the frost. This way there are extensive climatic hazards leading to the partial or total crop failure.

3. Undulation soil surface:- Soils in this region get eroded every year due water and wind, which leaves behind an eroded gulley or rill and it requires leveling but due to poor economy of the farmers the soil is left as it is and the crops are grown there in. Thus the surface gradually becomes highly undulating.

4. Extensive agriculture:- The type of agriculture adopted in dry areas always remains extensive due to lack of irrigation.

5. Relatively larger plot size:- Since there is no irrigation facility, therefore, smaller plots are not required and farmers use to keep much bigger plot sizes which make it easy to identify as a rainfed area.

6. Similar types of crops:- In case of dry land agriculture only drought resistant crops can be grown and almost all the farmers of the region use to grow similar crops. Thus the entire area can be seen under the same crop having poor growth and development and it can be identified as a rain fed area.

7. Lower crops yields:- Yields of various crops grown in dry lands are found to be very low as the farmers being very poor can neither apply full doses of inputs nor the improved seeds of high yielding varieties.

8. Poor market for the produce:- Since everyone uses to grow the same crops and they become ready for sale at the same time, they get less price for their produce because of poor demand and abundant supply rather a glut in the market.

9. Poor farmers economy and cattle health:- The farmers do not get proper return of their efforts hence their economy remains poor. Due to scarcity of fodder and feed the cattle are not healthy.

10. Widespread deficiency diseases in human beings:- Surplus of low calory food and short supply of vegetables, fruits, milk etc. cause deficiency of vitamins and minerals which result into malnutrition and deficiency diseases in human being.

Why crop failures are common, yields are not static under Rainfed farming because.....

1. Inadequate and uneven distribution of rainfall.
2. Late on set and early cessation of rainfall.
3. Prolonged dry spells during the crop growth period.
4. Low moisture retention capacity of soils.
5. Low fertility of soils, low humidity, higher temperatures, higher wind velocity.

HISTORY OF DRYLAND AGRICULTURE AND WATERSHED DEVELOPMENT

History of Rainfed Agriculture:-

Over the years, following efforts have been made to transform rainfed farming into more sustainable and productive systems.

1880-the First Famine Commission was appointed by the then British Empire to suggest ways and means to off-set the adverse effects of recurring droughts

1920-Scarcity trak development given important by Royal commission on Agriculture.

1923-Establishment and Dry farming Research station at Manjari (Pune)

1933- Dry Farming Research Station at Bijapur and Solapur

1934- Dry Farming Research Station at Hagari and Raichur

1935-Dry Farming Research Station at Rohatak (Panjab)

1942- Bombay land development act passed

1944- Monograph on dry farming in India by Kanitker

1950- Establishment of all India Coordinated Research Project for Dryland Agriculture (AICRPDA)

1953-Establishment of Central soil conservation Board

1955- Dry farming demonstration centers started

1959- Central Arid Zone Research Institute (CAZRI) was established in at Jodhpur.

1970-All India Coordinated Research Project for Dryland Agriculture (AICRPDA) was initiated in at 23 centres, selected on agro-climatic basis.

1972-International Crop Research Institute for Semi-arid Tropics (ICRISAT), Hyderabad**1976**- Renewed efforts were made by the Government of India in mid-fifties to conserve the natural resources and optimising their use by establishing eight Soil Conservation Research Centres at Dehradun, Chandigarh, Udhagamandalam, Bellary, Kota, Vasad, Agra and Hyderabad, which were put under the control of Central Soil and Water Conservation Research and Training Institute (CSWCR&TI), Dehradun

1977-KVK, Hayatager

1983-All India Coordinated Research Project on Agro-meteorology was started to strengthen the location specific weather forecasting.

1983-Starting of 47 maodel watershed under ICAR

1985-Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad

1986 Launching of NWDPRA programme by Government of India in 15 states.

History Of Watershed Development In India

1962-63 -Centrally Sponsored Scheme of "Soil Conservation Work in the catchments of River Valley Projects (RVP)" was launched

1973–74- Started Drought Prone Area Programme (DPAP) with an objective of Promote economic development and mainstreaming of drought prone areas through soil and moisture conservation measures.

1977–78- Started Desert Development Programme (DDP) with an objective of Minimize adverse effects of drought and desertification through reforestation.

1980- 81- The Ministry of Agriculture started a scheme of Integrated Watershed Management in the Catchments of Flood Prone Rivers (FPR).

1980- Several successful experiences of fully treated watersheds, such as Sukhomajri in Haryana and Ralegaon Siddhi in Western Maharashtra, came to be reported.

1982-83 The Ministry of Agriculture launched a scheme for propagation of water harvesting/conservation technology in rainfed areas in 19 identified locations.

1990- Concept of integrated watershed development was first institutionalized with the launching of the National Watershed Development Programme of Rainfed Areas (NWDPRA) covering 99 districts in 16 states

1992- Indo-German Watershed Development Programme for Rehabilitate micro-watersheds for the purpose of regeneration of natural resources and sustainable livelihoods, using a participatory approach by NABARD and the Watershed Organisation Trust (WOTR)

2009- Integrated Watershed Management Programme (IWMP) Consolidated three programs: IWDP, DPAP, and DPP. Programs adopted a cluster approach focusing on a cluster of micro-watersheds (1000 ha to 5000 ha scale) by MoRD.

PROBLEMS / CONSTRAINS OF RAINFED / DRYLAND AGRICULTURE

The low productivity of agriculture in dry farming regions is due to the cumulative effect of many constraints for crop production. The problems of crop production in dry land agriculture are mostly with vagaries of monsoon and soil constraints.
The constraints can be broadly grouped in to

A. Climatic constraints
B. Soil constraints
C. Socio economic constraints
D. Technological constraints
E. Crop production problems

A. Climatic constrains :

I) Rainfall

1. **Commencement of rains may be quite early or considerably delayed:** Normal onset of monsoon is towards the end of May over Kerala coast and by 15th July in the extreme north west part of Rajasthan. There is variability in the dates of onset of the monsoon from year to year.
2. **There may be prolonged 'breaks' (Dry spell):** There will be break in the monsoon associated either with weak monsoon current or with the temporary withdrawal of the monsoon. For breads of more than 2-3 weeks can affect the crop to varying degrees. Monsoon breaks for 7-10 days may not be serious concem. Breaks of more than 15 days duration especially at critical stages for soil moisture leads to reduction in yield. Drought due to break in monsoon may adversely affect the crops in shallow soil than in deep soils.
3. **The rains may terminate considerably earlier or persist longer than usual:** Withdrawal of the monsoon begins in the beginning of September in north western Rajasthan and disappears over Kerala towards the end of October. The date of withdrawal of the monsoon varies from year to year.
4. **Inadequate and uneven distribution of monsoon in space and time:** Monsoon may be excessive in one part of the country and deficient in another, and/or excessive during one part of the season and deficient during another.
5. **Intensity and distribution:** Distribution of rainfall is more important than total rainfall in Dryland agriculture in genetal more than 50% of total rainfall is usually received in 3 to 5 rainy days. Such intensive rainfall results in substantial loss of water due to surface runoff. This process also accelerates soil erosion.
6. **Late onset of monsoon**: Crops cannot be sown in time if on seal of monsoon is delayed. Delayed sowing leads to poor yield due to reduction in growing period in such cases.
7. **Early withdraw of monsoon**: This is more dangerous than late on seal of monsoon. Rainy season crops will be subjected to terminal stress leading to poor yield. Similarly post tiny season crops fail due to inadequate available soil moisture spectrally during reproductive and maturity phases.
8. **Seasonal variation**: 80 % rainfall received in June to September (*Kharif* season) while 20% rainfall received in remaining eight month.

(Vagaries of monsoon: According to average annual rainfall, the country can be divided into three distinct zones low (less than 750mm), medium (750-1150 mm) and high (more than 1150 mm) rainfall zones. Areas which receive less than 1150 mm rainfall characterized arid and semiarid are problematic in crop production. Rainfall variation intensity and distribution late onset early withdraw of monsoon and prolonged dry spell during crop growing period are main features influencing crop production in dry regions.

Rainfall variation: The annual rainfall varies greatly from year to year to crop failures due to uncertain rains are more frequent in the regions with lesser rainfall. The tremendous variation in rainfall is mainly due to geographical position of these tracts with reference to surrounding seas and the configuration of land surface. Other local factors like river lakes, forest also contribute to determine annual rainfall.)

II) **Wind velocity**: - Wind velocity is generally high during July and August. If wind velocity exceeds 18 - 20 km./hr. Such period coincided with dry spell. Hence Evapotranspiration is at high degree. If velocity is low the lowest evaporation rates are observed during November and December. High winds are experienced in association with cyclones, depressions and dust storms. High winds cause mechanical damage to crops like lodging and bread king. Light winds blowing from colder parts bring about a drop in temperature Warm and dry winds causes greater losses through evaporation and result in water stress.

III) **Bright sunshine hours**: - Bright sunshine is usually experienced during months of Jan. and Feb. At Solapur it is about 8 to 9 hours. During April and May the sky is usually have with more dust particles, lowest bright sunshine is noticed during Aug. (4 to 5 hours). This indicates the cloudy weather but no rainfall. Sunshine is not limiting factor in anywhere in India. During monsoon there is not a lack of sunshine but excessive rain is responsible for occasion set back to plant growth. However, continuous cloudiness during flowering is injuring to all plants. It also creates conditions favorable to the multiplication of pests and diseases. High humidity and warm temperature are conducive to most plant diseases.

IV) **Humidity:** - Humidity is high during July and Sept. During Feb. to May it is low. During dry spell, less relative humidity is noticed. Evaporation demands are also accelerated with high temperature and low humidity.

V) **Temperature: -** Maximum temperature exceeds 41^0 C during late April and early May. Minimum temp. is noticed during December. Lowest weekly minimum temperature is about 14 to 15^0C. Generally climate is semi and with mild winter and hot summer. Crop like wheat and gram requiring longer cool period hence do poor while prolonged cold weather however, Jowar suffers considerably. The air temperature is a decisive factor in plant growth. In India, high temperature are also of special importance as they may have damaging effect on crop during the period of water stress in arid and semi arid regions. Evaporation demands and also associated with high temperature and low humidity, which puts further limitation on crop growth.

B. **Soil constraints (Soils of Rainfed region):** Alluvial soils occupy the largest area in Dryland agriculture. The problems of crop production are not so acute in these soils. The major problems are encountered in vertisols, alfisols and related soils. Black (vertsols) red (alfisols) and associated soils are mostly distributed in central and south India. The coastal areas have alfisols, laterite and lateritic soils. The different soil constraints for crop production are

1. Inadequate soil moisture availability: The moisture holding capacity of soils in dry regions is low due to shallow depth especially in alfisols (red soils), low rainfall and low organic matter content.

2. Poor organic matter content: The organic matter content in most of the soils under dryland conditions is very low (< 1 %) due to high temperature and low addition of organic manures. Poor organic matter content adversely affects soil physical properties related to moisture storage.

3. Poor soil fertility: Due to low accumulation of organic matter and loss of fertile top soil by soil erosion the dry land soils are poor in fertility status. Most of the dry land soils are deficient in nitrogen and zinc.

4. Soil deterioration due to erosion (wind, water): In India nearly 175 m.ha of land is subjected to different land degradations, among them the soil erosion is very predominant. The erosion causes loss of top fertile soil leaving poor sub soil for crop cultivation.

5. Soil crust problem: In case of red soils, the formation of hard surface soil layers hinders the emergence of seedlings which ultimately affect the plant population. Crusting of soil surface after rainfall reduces infiltration and storage of rainfall, due to high run off.

6. Presence of hard layers and deep cracks: Presence of hard layers (pans) in soil and deep cracks affect the crop production especially in case of black soils.

C. Socio-economic constraints:

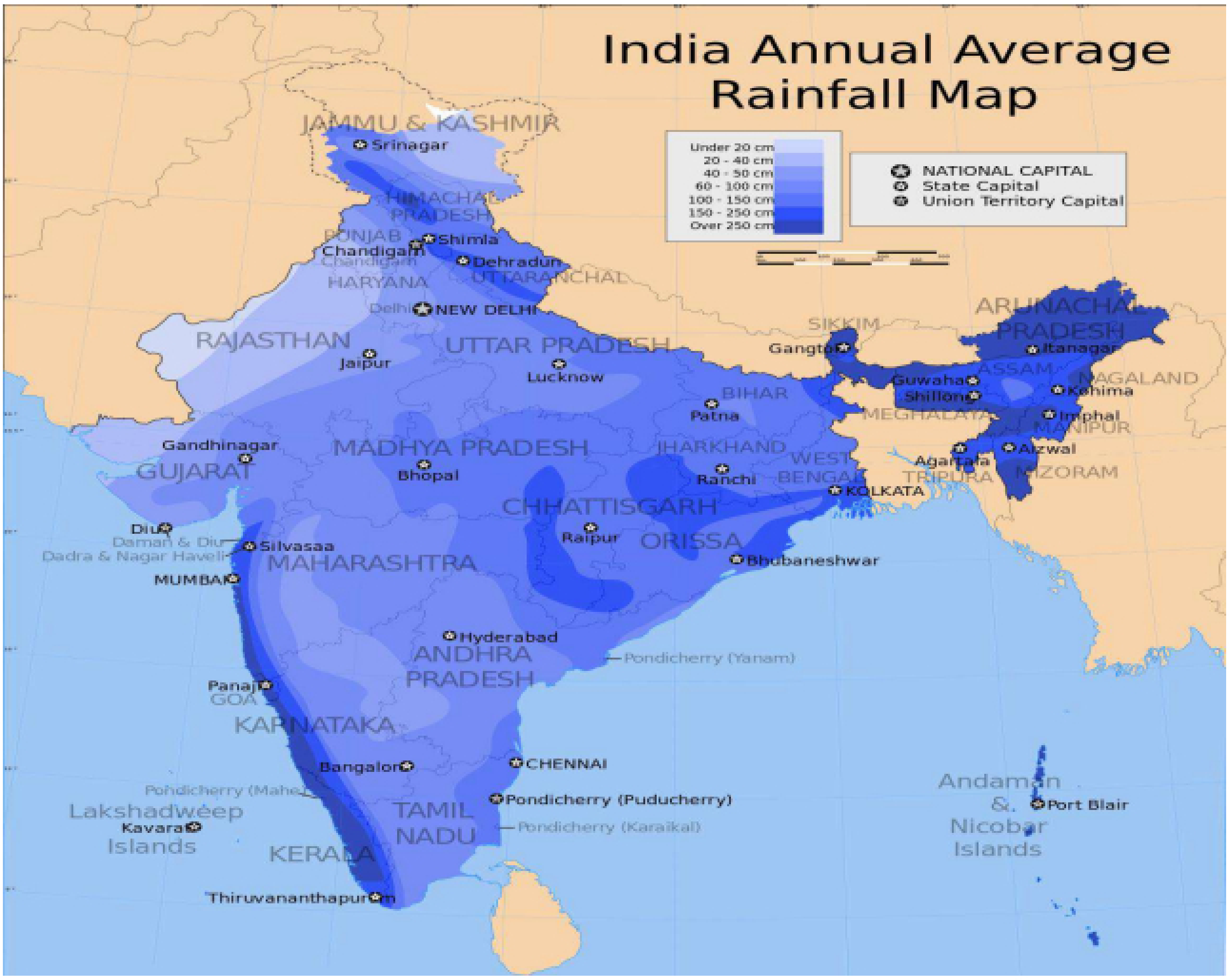
- Small land holding and high population pressure
- Frequent failure of crop and unstable production
- Low cropping intensity and low income
- Unemployment for most of the period of year.
- Lack of capital and financial aids
- Traditional attitude of farmers

D. Technological constraints:

- Lack of suitable genotypes giving high and stable yields under Rainfed condition.
- Problem in designing suitable cropping systems.
- High input based technology is risky.
- Limited use of fertilizers, poor response of bio-fertilizers and poor availability of organic manures.
- Limited scope of use of residual moisture and nutrients
- Problem in soil moisture conservation and timely utilization by crop.
- Limited scope for land improvement.
- Water harvesting and recycling are high investment preposition.

E. Crop production problems:-

-Unfavorable crop growth environment
-Severe limitation on the choice of crops
-Low crop intensity


India Annual Average
Rainfall Map
Under 20 cm
20 - 40 cm
40 - 50 cm
60 - 100 cm
100 - 150 cm
150 - 250 cm
Over 250 cm
NATIONAL CAPITAL
State Capital
Union Territory Capital
JAMMU & KASHMIR
Srinagar
HIMACHAL PRADESH
PUNJAB
Shimla
Chandigarh
Dehradun
UTTARANCHAL
HARYANA
Delhi
NEW DELHI
RAJASTHAN
Jaipur
UTTAR PRADESH
Lucknow
SIKKIM
Gangtok
ARUNACHAL PRADESH
Itanagar
ASSAM
Guwahati
Shillong
NAGALAND
Kohima
MEGHALAYA
Imphal
MANIPUR
Agartala
TRIPURA
Aizwal
MIZORAM
BIHAR
Patna
JHARKHAND
Ranchi
WEST BENGAL
KOLKATA
Gandhinagar
GUJARAT
MADHYA PRADESH
Bhopal
CHHATTISGARH
Raipur
ORISSA
Bhubaneshwar
Diu
Daman & Diu
Silvasaa
Dadra & Nagar Haveli
MUMBAI
MAHARASHTRA
Hyderabad
ANDHRA PRADESH
Pondicherry (Yanam)
Panaji
GOA
KARNATAKA
Bangalore
CHENNAI
Pondicherry (Mahe)
Pondicherry (Puducherry)
Lakshadweep
Kavarati
Islands
TAMIL NADU
Pondicherry (Karaikal)
KERALA
Thiruvananthapuram
Andaman & Nicobar Islands
Port Blair

AGRO-CLIMATIC ZONES

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.

Definition : An agro-climatic zone is a land unit in terms of major climate and growing period which is climatically suitable for certain range of crops and cultivars.

An ecological region is characterized by distinct ecological response to macro climate as expressed in vegetation and reflected in soils, fauna and aquatic systems. Therefore an agro-ecological region is the land unit on the earth's surface covered out of agro-climatic region when it is supper imposed on land form and kinds of soils and soil conditions that act as modifiers of climate and length of growing period.

Delineation of climatically homogenous regions has been an important attempt of agro-climatic analysis that received extensive attention since the 19th century. However, several approaches have been made in the past to delineate the land area into climatic regions for the purpose of the agricultural planning. These earlier approaches have major limitations of non-uniform application of the criteria used.

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 rainfall, temperature, topography, cropping and farming systems and water resources. The emphasis was on the development of resources and their optimum utilization in sustainable manner within the frame work of resource constraints and potentials of each regions. These zones were further divided into 120 sub zones under National Agricultural Research Project (NARP).

AGRO-CLIMATIC ZONE OF INDIA:

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.

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.

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 Rajesthan. 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 %).

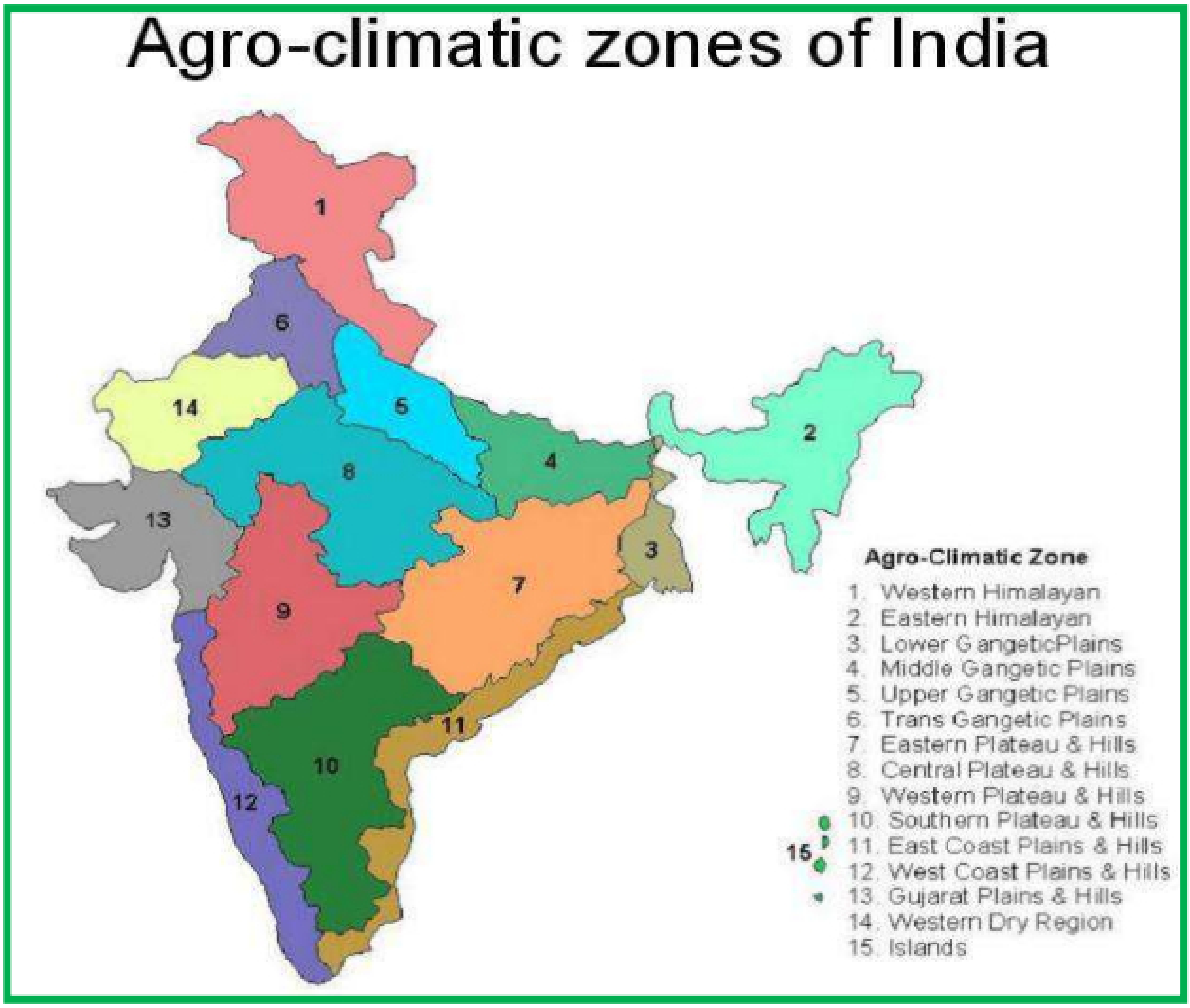
11) East Coast Plains and Hill Region : This zone comprises of east coast of T.N., Andhra Pradesh & Orissa. Soil is deep, loamy, coastal and deltaic alluvial type. Irrigation through canal and tanks. About 70 % land comes under rainfed farming.

12) West Coast Plains and Hill Region : The zone consists of west coast of T.N., Kerala, Karanataka, 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 zones comes under arid climate and covers 19 districts in Gujrant. 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^oC while in summer it is 45^oC. 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.



AGROCLIMATIC ZONE OF MAHARASHTRA STATE

Different agroclimatic zones of Maharashtra state with head office as given below

Zone	Head office
1) South Konkan costal zone	Vengurla
2) North Konkan costal zone	Karjat
3) Western Ghat zone	Igatpuri
4) Sub-mountain zone	Kolhapur
5) Western Maharashtra plain zone	Pune
6) Western Maharashtra scarcity zone	Solapur
7) Central Maharashtra plateau zone	Aurangabad
8) Central vidarbha zone	Yevatmal
9) Eastern vidarbha zone	Shindewai

The Maharashtra has large size and varied topography. The rainfall in the state varies from 50 cm in the Western Maharashtra scarcity zone to 400 to 500 cm in Ghat zones. Temperature though does not very much limiting factor for crop production like solar radiations. Soils also very from laterites in coastal regions, red and light brown in the hilly areas to heavy block clayey sols of varying depths in the plateaus. Taking into consideration the total annual rainfall pattern, the topography, soil characteristics and cropping patterns, the Maharashtra State has been divided into 9 broad agro climatic zones.

1) South Konkan Coastal Zone : South Konkan Coastal Zone comprises districts of Ratnagiri and Sindhudurg. The Zone lies between 15^0 13' to 18^0 50^0 N latitude and 72^0 45^0 and 74^0 50' E longitudes, with long and narrow strip of land measuring 260 km in length and width ranging between 50-60 km. The zone has an undulating topography with hills and rocky plains alternating.

Climate : The zone is characterized by warm and humid monsoon climate. May is the hottest month. About 97% of the rainfall is received during June to September from South West Monsoon. The average annual Rainfall is 3105 mm in about 101 rainy days.

Soils : Lateritic soil is the predominant type of soil observed in this zone. While along the sea coast, in a narrow belt, coastal saline and coastal alluvial soils occur. The intense leaching due to high rainfall has removed the bases from the soil profile giving it a distinctly acidic reaction (pH 5.5 to 6.5) .

Crops and cropping patterns : Paddy is the major cereal crop and Ragi (nagli) is the second important crop of the zone. Vari a minor millet is grown on hill slopes on low fertile soil during kharif. Oil seed crops like niger, Sesamum are also grown in kharif on limited areas. With introduction of irrigation, the area under Rabi groundnut, Sorghum and redgram is likely to increase. Due to typical soil and climate, the zone is ideally suited for horticultural crops viz, Mango, Coconut, Arecanut, Cashewnut, Jackfruit, Banana, Pineapple etc.

2) North Konkan Coastal Zone : This zone comprising districts of Thane and Raigad. The zone lies between 17^0 52' and 20^0 20' N latitude and 70^0 70' and 73^0 48' E longitude. The north south length of the zone is about 260 km with width of about 140 km in Thane district and 50 km in Raigadh district.

Climate : The zone is characterized by warm and humid climate. The average rainfall is 2607 mm in 87 rainy days. The maximum rainfall (41%) received in July.

***Soils* :** The predominant soils found in the Thane and northern part of Raigad districts are non lateritic coarse and shallow. The soils are neutral to acidic in reaction. Medium black soils occur in patches in the northern part of the zone. Southern part of Raigad has lateritic soils. These soils are acidic in nature. (pH 5.5 to 6.5)

Crops and cropping patterns : Paddy is the major crop accounting for 64%of the area under cultivation. Ragi and Vari are also important crops. Major fruit crops are banana and chicku in Thane and Mango in Raigad district. 32% of the area is under forest.

3) Western Ghat Zone : It includes hilly and high lying terrains around the Ghats of Amboli, Phonda and Amba in Kolhapur district, Koyna and Mahabaleshwar in Satara district, Lonawala and Khandala in Pune district, Kalsoobai hills in Akola taluka of Ahmednagar and Igatpuri and Trimbakeshwar in Nasik district.

Climate : Rainfall at high lying terrains ranges between 3000 to 6000 mm and the area is mainly covered by deciduous to semi deciduous forests (22 to 25 %).

Soils : The soils are mostly forest land and warkas (Light lateritic and reddish brown) with distinctly acidic and poor in fertility.

Crops and cropping patterns : The principal crops grown are paddy, ragi (nagli), vari Kodra, Kharif sorghum, groundnut, niger, gram etc. The sugarcane is grown as cash crop.

The horticulture is the priority need of the zone. The area is well suited for rainfed fruits like mango, cashewnut, Jackfruit, Kavanda, jamun etc.

4) Sub-mountane Zone : This zone is located on the eastern slopes of sahyadri ranges. It includes surgana, peth and Nasik talukas of Nasik district, Rajgurunagar, Maval, Mulshi, Velha and Bhor talukas of Pune district, Javali, Patan and Karad talukas of Satara district, Shahuwadi, Panhala, Karvir, Kagal, Bhudargad, Ajara, Gadhinglaj talukas of Kolhapur district and Shirala taluka of Sangali district.

Climate : The annual rainfall of the zone ranges between 1700 to 2500 mm which is received mostly through South West monsoon. The climate is characterized by relatively hot summer, humid rainy season and moderately cold winters.

Soils : The soils are reddish brown to black tending towards lateritic nature with varying depths and textures. They are generally acidic (pH 6 to 7).

Crop and cropping patterns : The cropping pattern is mainly dominated by **Kharif** cereals like paddy, sorghum, pearl millet, maize, ragi followed by groundnut and sugarcane. During **Rabi** sorghum, wheat, gram and lab-lab (wal) are the important crops.

Potato, chillies, tomato, brinjal etc. are the important vegetable crops being grown in the area, Guava, mango, banana and cashew nut are the important fruit crops.

5) Western Maharashtra Plain Zone : This zone includes areas in western tahsils of Dhule, Ahmednagar and Sangali and Central tahsils of Nasik, Pune, Satara and Kolhapur districts.

Climate : This zone has well distributed rainfall ranging from 700 to 1250 mm. The maximum rainfall is received from South-West monsoon from June to October. The period of water availability ranges from 120 to 150 days.

Soils : The topography, in general, is plain in the zone. The soils are predominantly greyish black with varying texture and depth ranging from 0.25 to 1.00 metre. The medium deep soils are dark brown in colour. The soils are clay loam in texture and moderately alkaline with pH ranging from 7.4 to 8.4. The clay percentage around 40.

Crop and cropping patterns : The principal crops are **kharif** and **rabi** sorghum, groundnut, pearl millet, wheat, sugarcane, green gram, black gram, red gram, gram, ragi (nagali) etc.

6) Western Maharashtra Scarcity Zone : This region includes Solapur, Ahmednagar parts of Satara, Sangali, Pune, Kolhapur, Dhule, Jalgaon and Nasik districts and parts of Aurangabad, Jalna, Bid and Osmanabad districts.

Climate : This area suffers from twin problems of low productivity and high instability as a result of inadequate and erratic rainfall. The annual rainfall is less than 750 mm which receives in about 45 rainy days. Two peaks in rainfall are observed, first during June/July and second during September, resulting in bimodal pattern of rainfall distribution. Besides, the dry spells of varying durations extending from 2 to 10 weeks at a stretch are experienced during July and August. The water availability periods varies from 60 to 140 days. Because of high temperature and high wind velocity, the PE value is more than 1800 mm resulting in a deficit of more than 60% in general.

Soils : The soils are vertisol with base saturated. They have montmorilonite type clay, which swells when wet and Shrink on drying producing deep cracks. They are low in nitrogen, low to medium in phosphate and usually rich in potash. The shallow soils (depth less than 22.5 cm) constitute 30% medium deep soils (between 22.5 to 90 cm) 45% and deep soils (above 90 cm) 25%. Shallow soils are suited for kharif cropping and deep soils for rabi cropping.

Crops and Cropping patterns : Kharif crops like pearl millet, sorghum, pulses, groundnut, sunflower are taken on shallow soils. The proportion of kharif cropping is about 25 to 30%, leaving a large proportion of area to rabi cropping. Sorghum, Safflower, gram, sunflodwer etc, are taken during **Rabi** season. The short duration pulses followed by rabi sorghum/safflower cropping system is remunerative on deep vertisols during better rainfall years. The Agro-forestry, Agro-horticultural and dry land horticultural systems are gaining importance during recent year.

7) Central Maharashtra Plateau Zone : This zone comparises of parts of Aurangabad, Jalna, Bhir and Osmanabad districts, major parts of Parbhani and Nanded districts, Complete Latur district. This zone includes entire Buldhana and Akola districts excluding southern parts of Washim and Mangrul pir talukas, whole of Amravati, excluding eastern part of Chandrapur, and morshi talkukas, Darwha and Pusad talukas of Yeotmal district, whole Eastern part of Jalgaon district, Shirpur taluka of Dhule, south Solapur and akkalkot talukas of Solapur district.

Climate : The average rainfall is 700-900 mm with 35 to 65 rainy days. In monsoon (June-September) , more than 75% of rainfall is received in all the district of this assured rainfall zone.

Soils : Soils are derived from Deccan trap and range from black to red colours. The soils are vertisols, entisols and inceptions. The pH ranges from 7 to 7.5.

Crops and Cropping Patterns : The sorghum is the predominant crop of the region. The the next important crop is cotton. The oilseeds (groundnut, sunflower etc.) and pulses (green gram, black gram, red gram, gram) contributes very little area. In plain area of Parbhani, Nanded, Jalna and Aurangabad, Kharif cum rabi cropping pattern is prevalent. Under irrigation, Kharif Sorghum-wheat and cotton summer groundnut are the important cropping systems.

8) Central Vidharbha Zone : This zone includes entire Wardha district, major part of Nagpur and yeotmal districts, two talukas of Western Chandrapur district, parts of Aurangabad, Parbhani, Jalna and Nanded districts. This is one of the large Agro-climatic zones of the state.

Climate : The average annual rainfall ranges between 950 to 1250 mm which received in about 59 rainy days. July is the wettest month.

Soils : Soils of the zone are derived from basalt rocks, black in colour and have varying depths. These soils are medium to heavy in texture, fairly high in clay content, alkaline in reaction, high lime reserves with high base saturation of the exchange complex. Vertisols swells after wetting and shrinks after drying producing deep and wide cracks.

Crops and cropping patterns : The cropping patterns involves cotton, kharif sorghum (30-40%), Red gram, wheat, pulses and oilseeds, paddy and rabi sorghum are also included in the rotation.

9) Eastern Vidarbha Zone : This zone includes entire Bhandara and Gad-Chiroli districts, eastern part of Chandrapur district and Umred tahsil of Nagpur district.

Climate : This zone receives average annual rainfall of 1250 to 1700 mm in 60-70 days. July is the wettest month.

Soils : Soils are chiefly derived from mixed parent rocks like granite, geneses and schists. They are yellowish brown to red in colour and are having pH in the range of 6 to 7. Some areas in the south and west have medium black soils.

Crops and cropping patterns : Paddy is the predominant crop the zone in Bhandara district during kharif, followed by pulses like lathyrus and gram in rabi. In Bramhpuri, Gad-chiroli and Sironcha taluks of Chandrapur district, paddy although is predominant crop is associated with rabi sorghum and pulses and oilseeds during rabi season. In Umred taluka of Nagpur district almost six crops including rabi sorghum, wheat, kharif sorghum, chillies, paddy and linseed together form the major crop pattern with greater area under rabi crops.

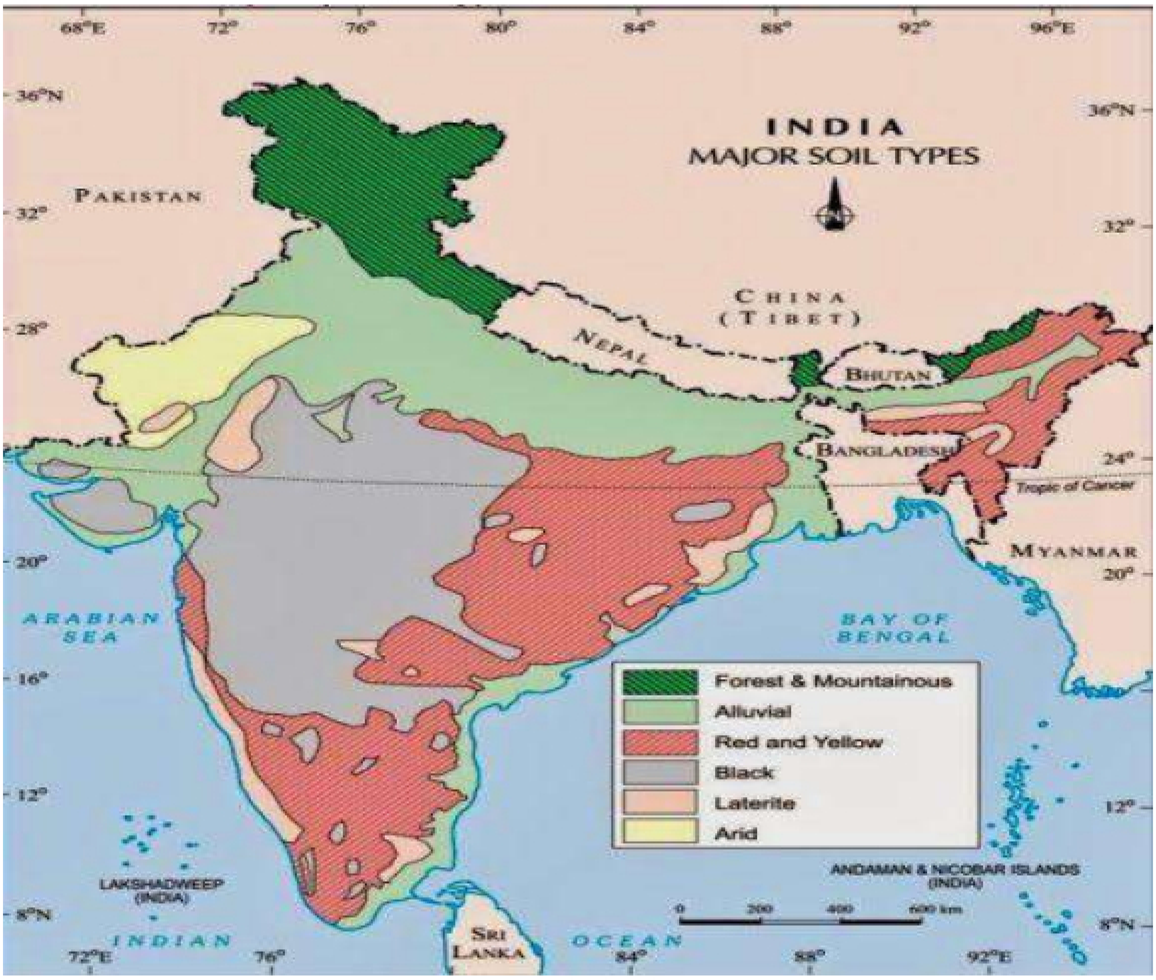

Nandurbar
Dhule
Jalgaon
Amravati
Nagpur
Bhandara
Gondia
Akola
Vardha
Buldana
Nashik
Washim
Yavatmal
Chandrapur
Aurangabad
Jalna
Gadchiroli
Thane
Hingoli
Ahmednagar
Parbhani
N
Mumbai
Beed
Nanded
Pune
Raigad
Osmanabad
Latur
Satara
Solapur
Ratnagiri
Sangli
Kolhapur
Sindhudurg
South Konkan Coastal Zone - Vengurla
North Konkan Coastal Zone - Karjat
Western Ghat Zone - Igatpuri
Sub-Montane Zone - Kolhapur
Western Maharashtra Plain Zone - Pune
Western Maharashtra Scarcity Zone - Solapur
Central Maharashtra Plateau Zone - Aurangabad
Central Vidharbha Zone - Yavatmal
Eastern Vidharbh Zone - Sindewahi
Place of the Headquarter
Agro-climatic Zones of Maharashtra

TYPES OF SOILS IN RAINFED AREA

1. **Alfisols:** Alfisols are, by and large, light textured soils which have low moisture holding capacity but high water intake. The rain water falling in such areas gets soaked up and saturates the profile. The soil water percolation is more and therefore, is lost for crop use. Owing to faster intake of water in the profile the surface runoff is limited and soil loss from erosion is low (3.05 t/ha/year). Soil crusting is a common problem in low rainfall areas. These are commonly referred to as red soils. The problems relation to crop production are (Geographical Area 20% Rainfall range 750-2000mm)
    - Poor crop stand due to crusting and rapid drying of surface.
    - Poor crop growth due to unreliable moisture supply low moisture storage capacity due to shallow depth and dry spell during crop season.
    - Low soil fertility due to low organic matter poor nutrient status particularly with respect of N.P.S and ca and compact sub soil layer (agrillic fiorson) and alnd degradation from soil erosion and crusting.
2. **Vertisols**: **(Black soil)** Vertisoles have high clay content and high moisture retention capacity. Owing to its swelling and shrinking characteristics, permeability is low and hence the rate of infiltration of water is minimum. This causes more surface and high soil loss from the top layer owing to surface erosion. It is estimated that 68.5 tones/ha per year soil is lost from vertisoles. Due to high clay content it develops cracks during Rabi season at flowering stage of crops. These soils commonly called as black soils with high clay content (30-70%). Important constraints for crop production are: (Geographical area 22%, Rainfall range 500-1500 mm)

    -Narrowing of soil moisture content for tillage
    -Tendancy to waterlogged and poor traffic ability.
    -Low fertility due to low N and available P and
    -Land degradation form soil erosion and salt accumulation.
3. **Inceptisols and Entisols (Alluvial soils)**: **Entisols** are generally loamy sand or sandy loam. Depth in these soils is not a constraint. These soils have very low clay content and hold water up to 200 mm per meter of soil profile. Its nutrient holding capacity is poor. In low rainfall areas monsoon cropping is practiced and in high rainfall areas double cropping is possible. These are commonly termed as **alluvial soils**. (Geographical area 21%)
    - Low water holding capacity
    - Low nutrient status
    - Management for crop production is relatively easy compared to red and black soils.
    - Land degradation is due to soil erosion.
4. **Submontane:** soils are medium in texture and depth is medium to deep as well as moderate in clay content. Moisture retention capacity is high (300 mm/m. profile). These soils are poor in nitrogen but medium in other nutrients. Phosphorous may be limiting in high production system. Due to high rainfall double cropping is possible in these soils.
5. **Sierozemic (Aridisoles)** are extremely light soils, effectively depth being influenced by the $CaCo_3$ concentration in soil profile. Its moisture holding capacity is low (150 mm water./m). Sierozemic soils are low in nitrogen and sometimes inadequate in phosphorous. Subsoil salinity is common. These soils are mostly monsoon cropped, except in deep sandy loams where post-monsoon cropping is also possible. Crusting is very frequent.

6. **Laterite soils:-** These soil occurs in Hills of Karnataka, Kerala, M.P., Eastern ghat of Orissa, Maharashtra, West Bengal, T.N., and Assam. Due to high rainfall it washes out the bases causing soil become acidic having pH 5.0 to 6.0. Soils are well drained having less water holding capacity of soils. Laterites have three varieties such as rice soil, warkas soils and garden soils. The soils are poor in Nitrogen, Occasionally P2O5 but K2O deficient.
7. **Forest and Hill soils:** These soils occur in hilly and forest area having high rainfall areas.
8. **Saline alkali soils**: These soils mostly Occurs in coastal areas Maharashtra such as parts of Ratnagiri, Raigad, Thane and Palghar district. Soils content larger amount of salts due to locally Known as kharlands.



CLIMATIC STUDIES OF RAINFED AREAS

Weather is a important factor which either directly or indirectly influences the crops. The principal weather elements which exert a strong effect on crop growth and yield are precipitation, temperature, winds, solar radiation, dew, fog and frosts.

1. Precipitation:- Rainfall has following main characteristics

Uncertain and erratic

Rains are generally insufficient or inadequate in arid and semi-arid regions

Intensity and distribution are uneven

Frequent dry spells and breaks.

Uncertain rains result in crop failures. Generally, yields are determined by the amount of precipitation above the basic minimum required to enable the crop to achieve maturity. Though, rainfall has major influence on yield of crops. Rainfall may also be in excess of the optimum and thereby cause reduced yields which may appear paradoxical to semi-arid climates.

2. Temperature:

-Temperature variation greatly affects the physiological and biological process of plants.

-Low temperature increases nutrient deficiencies due to low water uptake.

-At low temperature water is tightly bound to the soil and is difficult to absorb by the plant.

-High temperature causes loss of chlorophyll which result in chlorosis or yellowing of leaves.

- High temperature cause excessive transpiration which result in leaf scorch.

3. Humidity:

- In dry land region relative humidity always less 20-30% at mid-day, While in humid region it 60-70%.

- Low relative humidity increases transpiration rate and crop water requirement.

- When relative humidity is high, pollen may not be dispersed from the anthers.

- The incidence of insect pest and disease is high under high humidity condition.

- Very high or very low relative humidity is not conductive for high grain yield.

4. Winds:

- Wind increases transpiration and evaporation.

- Causes lodging of herbaceous plant.

- Causes soil erosion.

- Heavy winds accompanied by rainfall cause uprooting of crops.

- Hot dry wind affects photosynthesis.

- Winds with low temperature may produce chilling injury to the plant.

5. Solar radiation:

- The arid regions are characterized by predominantly clear sky during both day and night, permitting a large amount of solar energy to reach the earth.

- Solar energy provides two essential needs of plants. Light needed for photosynthesis and for many other functions of the plant. Thermal conditions required for the normal physiological function of plant.

- However, radiation also increases evapotranspiration.

6. Dew:-

- It provides a very small proportion of the water requirements of normally transpiring plants, but may be of some importance to plants under water stress.

7. Fog:-

- It affects plant growth through the high air-humidity, through wetting the aerial parts of plants and through humidification of the soil surface.

8. Frosts:-

- In warm regions, occasional and exceptional frost may do considerable damage because the crops grown in such regions are usually very susceptible to low temperatures.

Breakthrough to Enhance Crop Production in Dry lands:

The break through leading to a new order of yield in crop production in dry regions will most likely come from the long term team efforts of breeders agronomists and physiologist involved directly in experiments evaluation and decision making at every step of process.

Studies in AICRPDA and ICRISAT have come out with new recommendations to boost up the yields in dry land areas.

- Offseason and contour tillage in light texture red soils and optirnised minimum tillage in verticals.
- Early sowing to fully utilize the moisture availability period and make use of mineralized nutrients.
- Crop residue incorporation to improve moisture retention and nutrient status of soil.
- Crop and varietal selection based on moisture availability period.
- Contingent crop planning to meet vagaries of weather.
- Moderate use to fertilizers.
- Use of organic matter, bio-fertilizers and soil mulches to avoid rapid evaporation of soil moisture.
- Adoption of optimum plant population timely weed control and need base plant protection measures.
- In situ soil moisture conservation, water harvesting and recycling.
- Adoption of location specific intercropping and multiple cropping
- Adoption of suitable agro forestry and agrohorti systems.

Dry farming areas : Dry farming areas (as per the IV five year plan) are those areas receiving an annual rainfall ranging from 375 to 1125 mm and very limited irrigation facilities. Areas which receive less than 375 mm of average rainfall are considered as absolutely arid or desert areas, which require special treatment. As many as 128 districts in the country falls under category of dry farming areas as defined above. Out of these 25 dists from the states of Rajasthan, Sourashtra and rainshado region of Maharashtra and Karnataka belong to very high intensity dryfarming areas (i.e. rainfall ranges from 375 to 750 mm and irrigated area belong 10% of the cropped area.)

The major physiographic regions observed in India namely
i) Mountain region
ii) Indogangatic alluvial plains
iii) Peninsular or Deccan plateau &
iv) Coastal plains.

Rainfall distribution is based on:

1. Weekly or monthly rainfall will give distribution of rainfall in weeks during a crop season.
2. Wet and dry spells - A wet spell is a number of continuous days of rainfall. A dry spell is a number of continuous rainless days.
3. Rainy days: If the rainfall received is more than 2.5 mm on any day. This particular day is called rainy day.
4. Periodicity of rainfall.

5. Onset of monsoon.
6. Recurrence of rainfall events.
7. Dependability of rainfall
8. Coefficient of variation. If C.V. is more variation in rainfall is more and vice - a - versa.
9. Length of the growing season (LGS): If LGS is less a short duration crop should be selected. L.G.S. depends on duration of rainy season and moisture retention.

Rainfall being a single most important factor for success of crops in the dry farming areas. It is generally known that India receives its annual rainfall by the particular phenomenon called monsoon which consists of series of cyclones those arise in the Indian Ocean. These travel in the North East direction and enter the peninsular India along the Western coast. These cyclones occur from June to Sept. is known as south West monsoon. This is followed by second third and fourth rainy season during periods from Oct. to Nov., Dec. To Feb. and March to May respectively. South West Monsoon is the most important as it covers major parts of India and brings bulk of the total annual rainfall.

The North East of Returning monsoon: By the end of Sept. South West Monsoon ceases to penetrate North West India but continues a full month longer in Bengal. On account of south East North easterly winds being to flow on the Eastern coast. Some times some of these cyclones penetrate In land and give supplementary rainfall to dry region of the plateau of the peninsular India. This is known as returning monsoon.

Precipitation And Its Factors: Precipitation is reaching of atmospheric humidity either as rain or snow to the ground. OR Precipitation can be defined as earth word falling of water drops of ice particles that have formed by rapid condensation in the atmosphere and are too large to remain suspended in the atmosphere.

Factors influencing precipitation:-

1. Only blowing of winds coming even over the sea is not enough to produce precipitation.
2. Horizontal movement is not conductive to precipitation.
3. The rain bearing clouds, hills, mountains, slanting slopes of the river ralleys lake dynamic cooling of the clouds.
4. Water vapour in atmosphere and moat conditions which promote greater precipitation.
5. Regiour covered with thick forest contributes more water vapour by transportation and thus provide favorable condition for preciption.
6. The prevalence of dry winds, higher temperature absence of barriers and cutting of monsoon currents these are unfavorable for precipitation.
7. Long & short breaks in the monsoon caused due to prevalence of dry winds slowing over land or desert plains from North East.
8. On the other hand geographical position, physical configuration and meteorological conditions are responsible for precipitation.

Type Of Rainfall In Dry Areas

1. First type rainfall: Rainfall receives from south west Monsoon. Rainfall receives up to 60% in the first three months viz. June - July - August - Rontak Jodhpur Jalgaon.

2. Second type rainfall: Rainfall receives from south - West Monsoon (40 to 55%) and supplemented with North East Monsoon (40 to 50%) Pune. Wai A Nagar Raichur - Maximum rainfall receives in July & Sept.

3. Third type rainfall: Rainfall receives from North East Monsoon (60%) Solapur Bijapur a Karnataka.

4. Four type rainfall: Rainfall receives uniformly (Well distributed) from Both Monsoon currents, places of rainfall - Chennai. Total rainfall received in 5 to 6 months.

Decennial rainfall: The mean total rainfall received during past 10 years:

Winds coming over land surface from the North - East are dry and cold and man cause of breaks in the monsoon or they tend to decrease the rainful of a tract by diluting the moisture laden masses of the atmosphere. Indian be divided into three zones of the basis of rainfall.

A) Heavy rainfall zone: above 1250 mm.

B) Moderate rainfall zone: 750 to 1250 mm.

C) Low rainfall zone: Less than 750 mm annual rainfall.

The average rainfall of Solapur varies from 500 to 720 mm and had bimodal distribution. The first peak is usually experienced during June and Second during Sept. Rainfall during Sept. is more assured and is in the rage of 150 to 200 mm. Even though Monsoon sets in by the end of June, July and August are characterized by dry spells of varying duration (2 to 8 weeks at stretch) and frequencies 1 to 5. Usually dry speels of more that 4 weeks duration or 3 dry spells of 2 week duration result in failure off Kharif crops. Such occasions are observed twice in fire years. Usually high wind velocity (18 to 20 km / hr)

At Solapur under dry land areas year to year fluctuations are so much that there is no guarantee of a fixed quantity of rainfall. Generally rainfall starts in late June to early July. There is depression during late July to early August. Again there is good amount of rainfall in last Aug. and Sept. The rainfall totally recedes by mid October. This is the usual pattern of rainfall in draught prone areas. The probability of rainfall is more than half the normal is fairly good. (P = 0.58) during September.

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. Use of antitranspirants
6. Crop rotation
7. Contour cultivation
8. Cover management
9. Planting of grasses for stabilizing bunds
10. Planting of trees and afforestation
11. Selection of suitable cropping and alternate land use systems
12. Micro-watersheds

B. Mechanical practices :

1 Contour bunding
2 Graded bunding or channel terraces
3 Compartmental bunding:
4 Bench terracing
5 *Puetorican* type bench terracing
6 Conservation bench terracing (CBT):
7 Broad base terracing
8 Zing terracing
9 Broad bed furrow system
10 Trenching (CCT)
11 Gully and nalla control
12 Control of stream and river banks
13 Dead furrow
14 Sub soiling

A) 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. This practice was adopted where slope is < 2 % and erosion problems are not severe.

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 postrainy season on profile stored soil moisture. The main intention of fallowing is to provide sufficient moisture for the main postrainy 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 ***postrainy*** 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 run off and erosion, Improvement in soil structure and weed control.
5. **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.
6. **Crop rotation:** Continues growing of jowar or bajra crop causes more erosion, but if followed by a legume crops, which cover the soil, it causes less erosion and maintain soil fertility.
7. **Contour cultivation:** Tillage operation viz., Ploughing, harrowing, sowing and intercultural should be done across the slop of land. This help more infiltration of water, less run off and erosion and give higher crop yield.
8. **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. Near ness 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, sunnhemp 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.

9. **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.
10. **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.
11. **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.
12. **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.

B) Mechanical practices :

The above measures control erosion by good management practices. Mechanical methods are adopted to supliment the agronomical practices & when land slope is > 2 %. 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. Effective in arid and semi arid areas.

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. **Compartmental bunding:** This method is one of the cheapest rain water conservation techniques, suitable for rainfed vertisols having slope of less than 1%. The compartmental bunds are formed in a field with a size of $40m^2$ with dimensions of 8 m x 5m. The longest bund is usually formed across the slope while shorter bund along the slope. By this method the entire field is divided into small sections, which helps in storing the initial rainfall and permitting increased infiltration rate. This method ensures rational moisture distribution as well as optimum moisture for better germination of seeds.
4. **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 there by 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.
   -BT sloping inwrd- high rainfall area (> 750 mm/annum)
   -BT sloping inward- low rainfall area (< 750 mm/annum) with permeable soil of medium depth
5. ***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.*

6. **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.
7. **Broad base terracing**: Broad bed terraces are constructed in deep black soils with high clay content where deep cracks are developed in summer. A terrace is a combination of ridge and channel across the slope on a controlled grade. These terraces have wide base and low height of ridge and usually formed with machinery.
8. **Zing terracing:** Zing terracing is adopted in lands with 3 to 10%slopes. Zing terraces are constructed in medium to deep soils in moderate to high rainfall areas. The length of the field is divided into donar area and receiving area in the ratio of 2:1. The donar area is not leveled where lower receiving area is leveled. Zing terracing is adopted to cut down the length of slope, to harvest runoff from upper area for the benefit of crops grown in lower side and to ensure adequate drainage during periods of heavy downpours.
9. **Trenching:** Contour trenches are made in non agricultural and for providing adequate moisture to grow trees and grasses. Contour trenches are suited to grow dry land fruit crops. Trenches are usually 60 x 45cm in size. The spacing varies from 10 to 30m. The trenches are not continuous, but broken at interval of 60m. Rain water is held in these trenches for some time and facilitates growth of vegetation.
10. **Broad bed furrow system**: It is one of the most efficient land management practices recommended by ICRISAT for insitu moisture conservation. It controls runoff and erosion and facilitates infiltration of water into soil. It consists of broad raised beds with furrows of 30cm wide and 15 cm deep on either side of each bed. The width of bed is 120 cm from the centre of one furrow to the adjacent furrow.
11. **Gully or *nala* control:** Gully or nala control is very essential to prevent its extension and further destruction of cultivated lands and grasslands. The sloping sides are planted with grass and trees. Suitable temporary and permanent structures such as check dams, overflow dams, drop structures are also provided. Small gullies can be stabilized by converting them into paddy fields.
12. **Control of stream and river banks:** Vulnerable sharp bends nalas by the sides of the rods and river bends near village sites cause considerable damage to property. These should be protected by providing spurs, jetties, rivets and retaining walls. Adjoining areas should be stabilized under permanent vegetation. Spurs are constructed at an angle to reduce the velocity of water and there by enabling the flood water to flow away but deposit coarse sand which will cause obstruction to successive water currents from cutting into the bank and thus straightening their course.
13. **Dead furrow:** Instead of bunds, furrows are made across the slope to trap run-off and eroded soil. Water in the furrows slowly infiltrates in the soil profile.

In situ moisture conservation:- In the past, emphasis was given to contour bunding as a potential tool for soil and water conservation which was never widely adopted by dryland farmers due to :

- Substantial yield reduction in the pit near the bund due to removal of surface soil during construction of bund. Even when the advantage was there, it was only marginal
- Quantity of water held by the soil did not increase due to water trapped near the bund

- Delay in cultural operations and crop damage due to stagnant water above the bund considerably reduced the yield
- Increase in yield due to the effect of bunding could not compensate for the yield reduction due to area removed (**5**-10%) by bunds and soil excavation.

Bunding may be the last line of defence and the land between bunds should be treated culturally for effective moisture conservation. Appropriate land configurations like broad beds and furrows, inter-row and inter-plot water harvesting system etc. hold great promise for ***in situ*** water harvesting systems.

The in situ moisture conservation methods area as below

1. Broad Bed and Furrow (BBF)
2. Compartment Bund
3. Dead furrow
4. Opening ridges and furrows
5. Tie-ridging
6. Bedding system
7. Inter-row water harvesting
8. Inter-plot water harvesting
9. Scoop on land surface
10. Subsurface moisture barrier

STRIP CROPPING

It consists of growing of erosion permitting and erosion resisting crops in alternate strips along with the contours. It is an important agronomic means to asset the soil erosion-in-situ. It helps in display the entry of rain drop and obstructs the runoff. The practice is only for *kharif* season cropping. It can be adopted upto 40 cm depth of soil, undulating terraces upto 3% slope.

Erosion resisting crops:

These are the crops those which spread and cover the soil and do not allow runoff water to carry much soil with it. The soil, which flows from strips growing erosion permitting crops is caught by the alternating strips of erosion resisting (soil) crop. e.g. Groundnut, kidney bean, horse gram, mung, udid, stylo, soybean, which spread and cover to soil and do not allow runoff water.

Erosion permitting crops:

The erosion permitting (soil depleting) crops when grown in rows, allow the run off water to flow freely with the rows e.g. cotton, sorghum, pearl millet, red gram etc.

Some grasses are planted because their canopy and profuse root system tightly binds the soil against erosion, increase water infiltration and improved physical characteristics (structure and texture) suitable for cultivation.

Types of strip cropping:

i) Contour strip cropping: The strips of crops are arranged on contour at right angle to the natural slope of land. Usually strips are cropped in a definite rotational sequence. This is the most effective form of strip cropping.

ii) Field strip cropping: It is followed in areas too undulating or irregular topography of the direction of erosive force. Field strip cropping, consists of strips of uniform width, control of erosion by water, the strips run across general slope, but approximately on contour.

iii) Wind strip cropping: Narrow and parallel strips of erosion permitting and erosion resisting crops are arranged crosswise to the direction of wind. Alternate arrangement of erosion susceptible and erosion resistant crops in regular narrow strips.

iv) **Buffer strip cropping:** In this method , the strips of grasses or legumes are grown between contour strips crops in rotation. Buffer strip cropping provides protection to the land from soil erosion.

v) **Parmanent or temporary buffer strip cropping :** The strips are established particularly in steep or highly eroded slopes in the field. The strips are generally planted with perennial legumes, grasses or shrubs on permanent or temporary basis.

ANTITRANSPIRANTS

Antitranspirants are the materials/chemicals which applied to the transpiring plant surfaces with aim to reducing water loss from the plant. Approximately 99% of the water taken up by plant roots is transpired to the atmosphere through stomatal pores in the leaves.

Types of antitranspirants:

1) Stomatal Closing : Most of the transpiration occurs through stomata on the leaf surface. Some fungicides like phenyl mercuric acetate (PMA) and herbicides like atrazine in low concentration serve as antitranspirants by inducing stomatal closing. These might reduce the photosynthesis simultaneously. PMA was found to decrease transpiration to greater degree than photosynthesis in number of plants.

2) Film forming : Plastic and waxy material which form a thin film as external physical barrier on the leaf surface. However, a film which effectively retards transpiration, it increases the turgidity of the leaves and stomatal guard cells. The success of these chemicals are limited, since they also reduce the photosynthesis. The desirable characters of film forming antitranspirants are 1) They should form a thin layer 2) They should be more resistant to the passage of water vapour than carbon dioxide 3) The film should maintain continuity e.g. Silicones, Mobileaf, Hexadeconol.

3) Reflectant: These are white materials which form a coating on the leaves and increase the leaf reflectance (albedo), by reflecting the radiation. They reduce leaf temperature and vapour pressure gradient from leaf to atmosphere and reduce transpiration. Application of 5% Kaoline spary reduces transpiration losses. E.g. diatomaceous earth product (Celite), hydrated lime, calcium carbonate, magnesium, zinc sulphate, kaoline etc.

4) Growth retardants: These chemicals reduce shoot growth and increase root growth and thus enable the plants to resist drought. They may also induce stomatal closure e.g. Cycocel (CCC).

Antitranspirants are also useful for reducing transplantation' shock of nursery plants (Horticultural plants). Antitranspirants generally reduce photosynthesis. Therefore, their use is limited to save the crop from the depth under sever moisture stress.

Good features of antitranspirants:

Non toxicity
Non permanent damage to stomata mechanism
Specific effects on guard cells and not to other cells.
Effects on stomata should persist atleast for one week.
Chemical or material should be cheap and readily available.

Role of antitranspirants in annual field crops: In general field crops are highly dependent on current photosynthesis for growth and yield. Therefore, it is unlikely that currently available antitranpirant would increase yield of an annual crop unless the crop suffers stressed from inadequate water and/or a very high evaporative demand, particularly during a moisture sensitive stage of development.

Fuahring (1973) sprayed stomata inhibiting or film forming anti-transpirants on Sorghum under limited irrigation conditions, he found that grain yield increased 5 to 17 %. The application of antitranspirants just before the boot stage was more effective than later sprays.

Carbon dioxide is an effective antitranspirants. A little rise in CO2 concentration from the natural o.o3% to 0.05% induces partial closure of stomata. Its higher concentration cannot be used which results in complete closure of stomata affecting adversely the photosynthesis and respiration. However, usage of CO2 has one advantage that it inhibits photorespiration But CO2 usage cannot be economical and is practically feasible only in experimental glass house.

TILLAGE:

Tillage may be defined as the practice of modifying the state of soil in order to provide conditions favorable for plant growth. Tillage can also been defined as the mechanical manipulation of soil with certain implement or tools to provide a suitable environment for seed germination root growth, weed control, soil erosion control and moisture conservation.

Aims and objectives of tillage in rainfed farming:

1. Erosion control: - contour tillage contour cultivation tillage across the slope.
2. Weed control: - check weed growth & avoid moisture competition.
3. Management of crop residues: - Mixing of trash and decomposition of crop residues retention of trash on top layers to reduce erosion.
4. Improvement of tilth: - minimize the resistance to root penetration, improve soil texture & structure etc.
5. Improvement of soil aeration: - For good growth of crop.
6. Providing food seed - soil contact.
7. Preparing fine surface for seeding operation.
8. Incorporation of manures, fertilizers and agro chemicals (weedicide & soil amendments) into the soil.
9. . Insect control.
10. Temperature control for seed germination.

Minimum tillage or no tillage (zero tillage) concept in rainfed farming

In the recent past, minimum tillage concept come into existence for reducing time, labour and machine operations as well as conserving moisture and reducing erosion. The modern technology of herbicides & insecticides made it possible to achieve some tillage requirements without using implements. Any tillage practice in dry lands which does not return more than its cost by increasing yield and improving soil conditions should be eliminated. Soil need to be worked only enough to assure optimum crop production and weed control.

Minimum Tillage- It aims of reducing tillage operations to the minimum necessary for a reasonably good seed bed, favorable edapic environment for growth of crop. Advantage over zero tillage is improve soil physical condition due to higher water infiltration into subsoil, lesser resistance to root growth, less surface run-off. In all these primary tillage is as usual. However, secondary tillage is replaced by direct sowing in which the seed is covered with the equipment used for sowing. Minimum tillage is a method aimed at reducing tillage to the minimum necessary for ensuring a good seed bed rapid germination satisfactory stand and favorable growing condition.

Minimum tillage made practicable and economical because of:

1. Development of good equipments for combined tillage & sowing operations.
2. Enormous progress in chemical weed control which has reduced unnecessary many other tillage operations.
3. Minimum tillage frequently gives as good as or even better yields than conventional tillage methods.

Advantages of minimum tillage:-

1. Increases organic carbon.
2. Improves soil structure
3. Increases hydraulic conductivity of soil.

4. Increases infiltration of soil.
5. Reduce soil compaction.
More advantages in coarse & medium soils than heavy soils.

Disadvantage of minimum tillage:-

1. Seed growth / intensity is increased
2. Less decomposition of organic manures & release of nitrogen
3. Less germination of crop seeds.

Minimum tillage can be practiced by different Methods:-

A) Ploughing planting: - In this method only a single trip over field is required. The tractor pulls a plough & planter simultaneously. The seed row is centered on the furrow slice. The area between the rows remains ploughed & weeds do not germinate easily. This involves in less cost in seed - bed preparation and yields remain some to that of conventional tillage. The disadvantage in this method is that planting is slowed down & sowing is delayed beyond the optimum time.

B) Till planting :- (Special Till planter):- It prepares seed - bed & sows two rows in one operation. The seed - bed is prepared by an implement equipped with a narrow & deep penetrating sweep a wider & shallower sweep and selection of rotary her. The strip between the rows neither is nor disturbed.

C) Wheel track planting: - The field is ploughed as usual. The seedbed a prepared by wheels of the factor. The soil between rows remain rough & loose & absorb better moisture reduces runoff. Weeds seeds he dormant in loose soil until rainfall. Save 40% villager cost ploughing + planting of seed shout be done at one time to avoid drying of upper soil surface.

Zero tillage: It refers to tillage systems in which soil disturbances is reduced to sowing generals and traffic only and where weed control must be achieved by a genital nears. It can be considered as a extreme form of minimum tillage. Primary tillage it commonly avoided and secondary tillage restricted to Seedbed preparation in the row zone only. It is also known as no till. Zero tilled soil are homogenous in structure with high population of earthworms. Organic matter content increases due to less mineralization. Control of weeds is the main problem in zero tillage. Zero tillage a widely used in humid areas. Erosion losses and polities are minimized by zero tillage. Zero tillage will be useful concept where than.

i. Soils are subject to wind and water erosion
ii. Timing of tillage operation too difficult.
iii. Conventional tillage do not yield more.
iv. Requirement of energy and labour too high.

Concept of Minimum Tillage is Useful In Rainfed Farming

How the concept of minimum tillage or zero tillage is useful in Rainfed farming:

1. It has been pressed hearing the experimental findings that the conventional tillage practices do not give higher yields over the maximum tillage practices in dry lands & hence the minimum tillage concept is useful in reducing additional cost on unnecessary tillage practices. The practice of harrowing alone may serve the purpose of seedbed preparation.
2. Frequent tillage operations results in loosening the top soil layer frequently which is subjected to more soil erosion due to intense rains. The research findings in dry lands have indicated that the frequent tillage operations lead to higher soil erosion as compared to untilled or less tilled soils. Hence the minimum tillage concept is useful in dryland framing in reducing soil erosion.

3. The crop residues left over the soil surface acts as a much and helps in minimizing the evaporation losses. These crop residues also reduce the runoff losses, thus help in soil and water conservation in dry land.
4. The organic or crop residues get incorporated in top soil layers in subsequent period and increase the organic matter content of soils increase the infiltration rate of water reduce the bulk density increase the soil aggregation reduce the compaction of top soil layer thus increasing the productivity in dry lands.
5. Frequent tillage operations in dry lands also leads to formation of hard pans in heavy soils when worked under wet conditions & hence frequent tillage operations be avoided in heavy soils of dry lands.
6. The fine textured heavy soils of dryland posses the self cracking habit extending to the depth of one meter and thus serves the purpose of ploughing. **Hence such soils should not be ploughed every year.** The research findings have indicated that such soils can be ploughed once in three years.
7. The problem of weed control can be avoided by using the effective herbicides for various field crops in dryland. Thus, the tillage operations required for weeds control can be reduced under dryland conditions.
8. The concept of zero tillage is not applicable in any kind of Agricultural system including dryfarming at this stage since sufficient research information need to be generated for its successful application.

MULCHING

Spreading of crop residue in rows of the crop within 15 days after sowing

Mulching is a practice of covering the soil surface with organic materials such as straw, grass, stones, plastics etc. to reduce evaporation, to keep down weeds and also to moderate diurnal soil temperature. As the surface water infiltrate into the soil, colloidal soil particle are filtered out in the surface layer. This process impedes water flow into and through soil pores leading to surface scaling and soil compaction. Hence, reduced infiltration increase surface runoff. A modification of traditional mulching called vertical mulching has been developed for heavy soils where infiltration is a problem. Trenches are dug at 5-10 m intervals depending on slope at sizes of 30 x 60 cm across slope on grade. They are filled with stalk materials which keep the cracks open and allow better water intake.

Mulches play the important role in dryland areas. Because erratic and uneven distribution of rainfall, their by soil moisture may not be improved, run-off potential is also more. Effectiveness of mulch is more visible in low rainfall area than normal rainfall .

Benefits of mulches as- reduce evaporation losses.

- Conserve moisture
- Increase infiltration
- Increase organic matter content
- Increase water holding capacity of soil
- Moderate soil temperature
- reduce weed problems.

Use of Mulches: The practice of applying mulches to soils is possibly as old as agriculture itself (Jacks et al 1955). Ancient Romans placed stones on the soil surface to conserve water and the Chinese used pebbles from stream beds for similar purpose. These practices were suitable to areas where hand labour was readily available; but become impractical when mechanized agriculture was introduced. The current trend under mechanized agriculture was introduced. The current trend under mechanized agriculture is to utilize crop residues as mulches on the area where grown or to use transported and manufactured materials as mulches for some high value crops.

In rainfed agriculture soil moisture is the limiting factor, soil moisture is lost by evaporation' through soil surface and 'Transpiration' through plant.

The evapotranspiration losses can be reduced by applying mulches, using antitranspirants planting windbreak plants and by weed control.

Reasons for using Mulches

Mulches are used for various reasons, but water conservation and erosion control are the most important for agriculture in dry regions. While, the effectiveness of mulches for water conservation is highly variable, mulches when properly managed definitely aid wind and water erosion control.

Mulch is any material applied on the soil surface to check evaporation and improve soil water, soil conservation moderation of temperature, reduction in soil salinity, weed control and improve soil structure and more infiltration.

Type of Mulches:

Materials used for mulches are crop residues, leaves, clippings, bark manure, paper, plastic films, petroleum products gravels etc.

1) Soil or Dust mulch: If the surface of the soil is loosened, it acts as mulch for reducing evaporation. This loose surface of soil is called soil mulch or dust mulch. Interculturing creates soil mulch in growing crops and helps in closing deep cracks in vertisols.

2) Crop residues or stubble mulch: Crop residues and other plant waste products viz. straw, cloves, leaves, corn .sawdust, are widely used as mulch. These materials are cheap and often readily available. They permit water to enter in the soil easily when maintain at adequate level. These materials results in increased water content and reduced evaporation. Amongst the mulches tried light and thin stem material like dry grass was most effective as others because of its heavy weight and less canopy (cover). Use of mulch @ 5 tons/ha. found to be most effective in dry farming area.

The mulch should be applied immediately after crop emergence to get optimum advantage. When these mulches are used the other crop operations like inter-culturing are not feasible hence saving in cost of cultivation.

The effectiveness of various other materials as a mulch has been investigated these materials have favorably influenced soil water content by reducing evaporation, but there use does not appear practically under large scale conditions e.g. gravels, stones, granular materials, manure etc.

3) Plastic films: Plastic films are more widely used as mulch. They help in maintaining higher water content of soil resulted from reduced evaporation, induced infiltration, reduced transpiration from weeds or combination of all these factors. They are relatively expensive and difficult to manage under large scale field conditions for low value crops e.g. Polythene Polyvinyl.

4) Petroleum products: These are less expensive than plastic films and more readily applicable materials e.g. petroleum, resigns etc.

5) Vertical mulch : Rainfall in dry farming area is with high intensity due to moderately slow rate of infiltration the run off is heavy. The water thus running as runoff could be stored in profile itself. Recently a new technique has been evolved to tap such water.

Vertical mulch is a technique which consists of digging suitable trenches across the slope and thus making more surface are available for water absorption. The open trenches are likely get silted in short period. This however, can be prevented by inserting organic farm waste material like straw, stubbles or stalks which is called filter. The filter should be resistant to decomposition and provide service for 3-4 years, Such trenches at suitable intervals provide portion of low density which helps to intake water at higher rates. Water thus percolates in a trench and gets distributed in the profile. The width of trench should be adjusted in such a fashion that least area remains uncultivable. If trench could be accommodated between crop rows there is practically no area wasted for trenches. Width of 20 cm 30x60 cm ideally suited for this purpose. Depth of trench in black clay soil should be upto murum level and distance between two trenches may be about 5 - 10 m interval.

Effects of Mulches on soil Properties and Conditions: Numerous soil properties and conditions are affected by mulches, either directly or indirectly. Among those affected are soil water through runoff control, increased infiltration, decreased evaporation, weed control, soil temperature through radiation shielding heat conduction and trapping and evaporative cooling, soil nutrients through organic matter additions, differential nitrification, and mineral solubility, soil structure, soil biological resume through organic matter additions, microbial and soil fauna populations, and plant root distributions; soil erodibility and soil salinity through leaching and evaporation control. Probably of greater importance however, for agriculture in dry regions are soil water, temperature, structure and salinity.

Effect of mulch on soil water: In dry regions generally receive inadequate precipitation for good crop production. Further more, much of the precipitation that is received is lost by runoff and evaporation, Application of mulches improves soil water by reducing evaporation surface run-off, weed population and by increasing infiltration.

The greatest amount of research with mulches concerned crop residues and other plant waste products (Straw, Stover, leaves, Corn cobs, sawdust, Woodchips etc.) These materials are cheap and often readily available, and they permit water to enter the soil readily, when maintained at adequate levels, these materials resulted in increased water contents and reduced evaporation.

Effect of mulches on soil temperature: Different mulches have variable effects on soil temperature colour of plastic mulches greatly affected soil temperature. White or reflective plastic decreased temperature or has no effect while clear plastic consistently resulted in higher temperatures than bare soil (Adams, 1970). The results of black plastics were variable petroleum spray Mulches of plant residue moderate the soil temperature by decreasing in summer and by increasing in winter.

Effect of mulches on soil Structure: In dry regions the precipitation frequently occurs in high intensity storms. When falling raindrops strike bare soil, soil particle are dispersed and surface sealing may occur, thus reducing infiltration. Consequently, Water that could be conserved for plant use is lost by runoff. The dispersed soil at the surface often forms a hard crust when dry which may adversely affect seedling emergence and plant growth.

Beneficial effects on soil structure due to surface mulches result primarily from the mulches absorbing the energy of falling raindrops, thus reducing dispersion and surface sealing. Crop residues and other similar mulches, when applied at adequate levels, have maintained high infiltration rate and resulted in less soil crusting (Mannering and meyer, 1963). The high infiltration rates resulted from less surface sealing due to the protection of mulches resulted in improved soil aggregation.

Effect of Mulches on soil Salinity: Many dry region soils have a high salt content. Since some of the salts are readily soluble in water, they move with the water. The salts could be removed from the soil by leaching if precipitation were adequate. However, due to limited precipitation, they move only a limited depth and readily return to the soil surface as water evaporates.

Mulches maintains infiltration rates and reduces evaporation. Which helps for reducing effect of soil salinity

Effects of Mulches on Erosion: Due to low residue production and dry soil surface conditions, dry regions are highly susceptible to wind erosion. Dry regions are also highly susceptible to water erosion because the precipitation frequently occurs during intense storms and surface is inadequately protected by vegetation to effectively retard runoff. Therefore, to reduce erosion by wind and water is an important reason for using mulches in dry regions.

Effects of Mulches on plants : The effects of mulches on plant are operative through the effects of mulches on soil water, temperature structure, salinity and erosion. The most critical periods in the life cycle of a plant is the period of germination, emergence and seedling establishment. Mulches can aid germination, emergence and seedling growth by moderating and improving the soil and aerial environment to which seeds and seedlings are subjected.

Different types of micro watersheds are as follow:-

a) **Ridges and furrows:** Ridges and furrows are suitable for 0.2 to 0.4 per cent slope. This type of land configuration is useful in conserving moisture in widely spaced crops like cotton, maize, sorghum, castor and pigeonpea.

b) **Ridging and tied ridging:** It involves making ridges and furrows, then tying or damming furrows with small bounds to increase the surface water storage and avoid run-off. The tie act as a barrier for the rain water movement and increases time available for infiltration, thus enhances the availability of soil moisture to the crops.

c) **Catch pits or scoop:** In this method, pits of different size are dug at many places in the fields to collect the run-off water along with silt. This will enhance the moisture availability to the crops.

d) **Broad bed and furrow system:** This land configurations consists of a relatively raised flat bed of approximately 90 to 150 cm width (depending upon the soil type and crop requirement) followed by shallow furrow of 30 cm width and 15 cm depth. The beds are maintained permanently. The beds function as mini bunds at a grade and help in reducing the velocity of surface run-off and increase infiltration opportunity time. The excess water is removed through the furrow.

DROUGHT

Extreme crop stress and wilt conditions. This situation arises due to scanty precipitation or by erratic distribution. Deficiency of rainfall has been principle criteria for defining agriculture drought. It is not only region specific but also crop specific.

The term drought can be defined by several ways.

1. The condition under which crops fail to mature because of insufficient supply of water through rains.

2. The situation in which the amount of water required for transpiration and evaporation by crop plants in a defined area exceeds the amount of available moisture in the soil.

3. A situation of no precipitation in a rainy season for more than 15 days continuously. Such length of non-rainy days can also be called as dry spells.

Drought is a period of inadequate or no rainfall, over extended time, creating soil moisture deficit and hydrological imbalance.

"Deficiency of available soil moisture which produces water deficits in the plant sufficient to cause a reduction in plant growth. **or**

"Drought is a period of inadequate or no rainfall over extended time creating soil moisture deficit and hydrological imbalances."

Particulars	Aridity	Drought
Duration	Permanent feature	Temporary condition of scarcity of varying duration
Factors	Culmination of many long term processes, considers all climatic features	Caused by deficient rainfall
Aspect described	Description of Climate	Description of Water availability

Classification of Drought

A) On the basis of source of water availability	B) On the basis of occurrence	C) On the basis of media
1) Meteorological drought :- Slight, Moderate and Severe 2) Agricutural drought 3) Hydrological drought 4) Socio - economic drought	1) Permanent drought 2) Seasonal drought 3) Contingent drought	1) Soil drought 2) Atmospheric a drought

1. **Meteorological Drought: -** If annual rainfall is significantly short of certain level (75 per cent) of the climatologically expected normal rainfall over a wide area, then the situation is called meteorological drought. In every state each region receives certain amount of normal rainfall. This is the basis for planning the cropping pattern of that region or area.

   India meteorological Department (IMD) has defined meteorological drought as the situation when actual rainfall is less than 75% of the normal rainfall over an area. It is further classified as moderate drought if the rainfall deficit is between 26-50% and severe drought when the deficit exceeds 50% of the normal.

The meteorological drought mainly indicates deficient rain of different quantum, which may cause hydrological and agricultural, soil and atmospheric drought reducing agricultural and industrial production. The Indian Meteorological Department has classified the drought as fallows on the basis of the rainfall departure.

1. **Slight drought: -** When rainfall departure is –11 to –26 % from the normal rainfall.
2. **Moderate drought: -** When rainfall departure is –26 to 50 % from the normal rainfall.
3. **Severe drought :-** When rainfall departure is –50 or more of the normal rainfall.

Drought prone area :- A drought prone area is defined as one in which the probability of a drought year is greater than 20%.

Chronic Drought Prone area :- A chronic drought prone area is defined as one in which the probability of a drought year is greater than 40%.

Rainfall conditions:-

i) Excess - 20% more than average of 70 - 100 yrs.
ii) Deficient - 20% less than average of 70 - 100 yrs.
iii) Deficient - 20 to 59% less than average of 70 - 100 yrs.
iv) Scanty 60% less than average of 70 - 100 yrs.

Drought years the year is considered drought when less than 75% of the normal rainfall is received.

2. **Agricultural Drought:-**This is a situation, which is a result of inadequate rainfall and followed by soil moisture deficit. As a result, the soil moisture falls short to meet the demands of the crops during its growth. Since, the soil moisture available to a crops insufficient, it affects growth and finally results in the reduction of yield.

   It occurs when the soil moisture and rainfall are inadequate during the growing season to support healthy crops growth in maturity and causes extreme stress and wilting.

   Agricultural drought constitutes a great hazard to agriculture in both the temperate and tropical region of the world

Causes of agriculture drought are-

1) Inadequate precipitation
2) Erratic distribution of rainfall
3) Late onset of monsoon
4) Early withdrawal of mansoon
5) Long dry spell during monsoon
6) Insufficient irrigation facilities
7) Inadequate evaluation of climate

- Severity of the agriculture drought is judged on the basis of aridity index

$$AI = \frac{PET\text{-}AET}{PET} \times 100$$

The variation of AI from its corresponding normal value is known as AI anomaly. Based on AI anomaly , the intensity of agricultural drought classified as

Sr.No	AI	Severity class
1	< 0.5	Moderate
2	0.5 to 1	Large
3	1.0 to 2	Severe
4	> 2.0	Disastrous

3. **Hydrological drought:-**This is a situation in which the hydrological resources like streams, rivers, reservoirs, lakes, wells etc dry up because of marked depletion of surface water. The ground water table also depletes. The industry, power generation and other income generating major sources are affected.

   Hydrological drought occurs when the surface and ground water resources are too inadequate to meet the demand for water.

   Prolonged results in hydrological drought with marked depletion of surface water and consequent drying of reservoirs, lakes, streams and rivers, cessation of spring flows and fall in the ground water table.

   Definition of hydrological drought is concentrated with the effects of dry spells on surface & sub surfaces hydrology rather than with the meteorological explanation of the event. Linsley et al. (1975) considered hydrological drought as "a period during which stream flows are inadequate to supply established used under given water management system". The frequency and severity of hydrological droughts often defined on the basis of water depletion or shortage in reserve basins, reservoirs lakes wells etc. This drought affects industry and power generation.

4. **Socio-economic drought :**

   The socio-economic effects of drought can also incorporate features of meteorological, hydrological and agricultural droughts. They are usually associated with the supply and demand of some economic goods. This drought should be linked not only to precipitation (supply) but also to trends or fluctuations in demand.

5. **Permanent Drought: -** This is characteristic of the desert climate where sparse vegetation growing is adapted to drought and agriculture is possible only by irrigation during entire dry period. It is found in the arid areas where there is not enough precipitation to satisfy the water need of plant. In such area, agriculture is impossible without irrigation throughout the crop season. Otherwise, only the crop of short duration with less water requirement can be grown.

   This is the drought area of permanent dry arid or desert regions. Crop production due to inadequate rainfall is not possible without irrigation in these areas. Vegetation like cactus thorny shrubs, xerophytes etc are generally observed.

6. **Seasonal drought: -** this is found in the climate with well defined rainy and dry seasons. Most of the arid and semiarid fall in this category. Duration of the crop varieties and plantting dates should be such that the growing season should fall within rainy season.

   It occurs in area with well-defined wet and dry seasons, as in most parts of the tropics. Drought can be expected every year owing to seasonal changes in atmospheric circulation patterns. Agricultural is possible during rainy season or with the use of irrigation during dry season.

In the regions with clearly defined rainy (wet) and dry climates seasonal droughts may result due to large scale seasonal circulation. This happens in monsoon area.

7. **Contingent drought: -** This involves an abnormal failure of rainfall. It may occur almost anywhere specially in most parts of humid or sub humid climate. It is usually irregular and generally affects only a small area. It is characteristic of the humid and sub-humid areas and occurs over a period of time when rains fail. Contingent drought constitutes a serious hazard to agricultural because of its unpredictability (e.g. monsoon breaks).

   This results due to irregular & variability in rainfall especially in humid & sub humid regions. The occurrence of drought may coincide with critical crop growth stages resulting in severe yield reduction.

   a) ***Early season drought :*** Early season droughts occur in association with the delay in commencement of sowing rains. Sometimes, early rains may occur tempting the farmers to sow the crops followed by a long dry spell leading to withering of seedling and poor crop stand.
   b) ***Mid-season drought :*** Mid season droughts occur in association with the breaks in south-west monsoon. Drought conditions during vegetative crop growth phase might result in stunted growth, low leaf are development and even reduced plant population.
   c) ***Late season drought :*** Due to early cessation of rainy season sometimes crops may encounter moisture stress during its reproductive phase which leads to forced maturity of crops due to rise in temperature. The grain yield of field crops is highly correlated with the water availability during the reproductive phase of crops growth.
   d) ***Apparent drought :*** While the rainfall in the region may be adequate for one crop but may not be so for others. For example paddy is grown in some of the sub-humid regions where it should not be grown. Whenever there is failure of rain in these areas, the rainfall may not be sufficient for paddy but the amount may be sufficient for some other crops like maize, sorghum, finger millet etc. whose water requirement is much less than that of paddy. Therefore, apparent drought conditions are encountered due to wrong selection of crops not commensurate to the rainfall/moisture availability patterns in some of the region.

8. **Soil drought :**

   It is the condition when soil moisture depletes & falls short to meet the potential Evapotranspiration (PET) of crop.

9. **Atmospheric drought: -** It is due to low air humidity, frequently accompanied by hot dry wind.

   This results from low humidity, dry and hot winds & causes desiccations of plants. This may happen even when rainfall & moisture supply is adequate. It can be defined on the basis of vapour pressure deficit over the crop or lower atmosphere, which may lead to no rainfall for prolonged periods. When the atmosphere is dry and warm temperature prevails along with, dry wind, plants wilt even if irrigation is provided due to advection effect. Such situation may lead to atmospheric drought.

Other terms to describe drought

- **Invisible drought: -** This can be occur even there is frequent rain in an area. When rainfall is inadequate to meet the evapotraspiration losses, the result is border line water deficiency in soil resulting in less than optimum yield. This occurs usually in humid regions.
- **Physiological drought :** It occurs when plant function fail physiologically due to water logging or water deficit. In fact the definition of physiological drought should be based on both water deficit and excess water, unlike in other types of drought.

- **Chronic drought** is common in arid areas where rainfall and stored soil moisture are inadequate to meet crop water requirement during most of the years. Here, the assured growing period is hardly 6 to 7 weeks. These are characterized as chronic drought or highly drought prone areas.
- **Apparent drought** conditions are observed in low to medium rainfall regions due to mis-matching of the cropping pattern in relation to rainfall / moisture availability.
- **Relative drought**: The drought for one crop may not be a drought situation for another crop. This is due to mismatch between soil moisture condition and crop selection. For Eg. A condition may be a drought situation for growing rice, but the same situation may not be a drought for growing groundnut.

MITIGATION AND CROP ADAPTATION TO DROUGHT OR DRY GROWING CONDITIONS

I	**Escaping drought**
	1. Ephemerals
	2. Early varieties
II	**Drought resistant**
	1. Drought/Stress avoidance
	A)Water savers (restricting transpiration) (Water conserving)
	-Early stomata closer
	-Increased photosynthetic efficiency
	-Low rate of cuticle respiration
	-Lipid deposition on foliage
	-Reduced leaf area
	-Morphology of leaf surface (Leaf area, stomatal location and frequency, presence of awans)
	-Water storage in plant
	B) Water spender (accelerating water uptake)
	-Efficient root system
	-High root/top ratio or root/root tip ratio
	-Increase osmotic potential
	2. Drought/stress tolerant
	i) Mitigating stress
	-Resistant to dehydration
	-Thick cuticle
	-Maintenance of high osmotic pressure
	ii) High tolerance
	-Metabolic strain
	-Plastic strain

Escaping drought:

Short duration crops which complete its life cycle in an extremely short growing season called as ephemerals. Evading the period of drought is the simplest mean of adaptation of the plant to dry condition. Many desert plant called ephemerals, germinate at the beginning of the rainy season and have an extremely short life period (5 to 6 week) which is confined to the rainy period. These plants have no mechanism for overcoming moisture stress and are therefore not drought resistant.

What is Drought Resistance?

It is the ability of a plant to maintain favorable water balance and turgidity even exposed to drought conditions there by avoiding stress and its consequences. Stress avoidance due to morphological anatomical characteristics which themselves are the consequences of the physiological processes induced by drought these xerophytic characteristics are quantitative and vary according to environmental conditions. A favorable water balance under drought conditions can be achieved by transpiration before as soon as stress is experienced. These are called **"water savers"** or. Accelerating water uptake sufficiently so as to replenish the lost water called as **"water spenders"**

A) The mechanism for conserving water (Water savers):-

1. Stomatal mechanism: -Stomata of different species vary widely in their normal behaviour and range. In some species stomata remain open continuously or remain closed continuously. Many cereals open their stomata only during a short time in the early morning and remain closed during rest of the day. There is a difference in this respect between varieties of the same crop as shown by the example in two varieties of oat one is more resistant to drought open its stomata more rapidly in the early morning when moisture stress is at its minimum and photosynthesis can precede with the least loss of water. However mechanism of conserving water based on the closure of stomata will inevitable load to reduce photosynthesis and may lead to drought induced starvation injury. (Opening stomata for short time in early morning & remained closed during rest of day when moisture stress is minimum with photosynthesis with the least loss of water e.g. varieties of wheat, oats).

2. Increased / Photosynthetic efficiency :- On the possibility for overcoming limitations on photosynthesis, imposed bicoastal closure as means for increasing resistance to loss of water by transpiration there by accumulations of CO_2 would be at higher rate for a given stomatal opening. A number of imperfect crop plants (maize, sugarcane sorghum , fox tail & finger millets) as well as certain forage species Bermuda grass Sudan grass Bahia grass (Rhodes grass and certain A triplex sp. fixed most of CO2 into the C4 of molic and aspartic acids so called C4 dicarboxylic acid (C4) pathway.

The plant species using the pathways have a high rate of carbohydrate assimilation for given stomatal opening higher temperature & light optimum e.g. maize sorghum.

3. Low rate of cuticle transpiration: - The typical example is the cactus. Thick cuticle results in low rate of transpiration.

4. Decreasing transpiration by a deposit of lipids layers on the surface of the leaves: - On exposure to moderate drought conditions the lipids are deposited on leaf surface which in reduction transpiration losses e.g. soybean

5. Reduce leaf area: - Rolling or curling of the leaves reduces the leaf surface exposed to sunlight thus helps in reducing the transpiration loss under stress conditions. E.g. Maize, Sorghum, grasses etc. The principle means of reducing water loss of xeromorphic plants is their ability to reduce their transpiring surface. Apart from the common means of keeping the aerial parts small perhaps the simplest form of this reduction of the transpiring surface is the sealing or of leaves at the time of water stress a characteristic phenomenon exhibited by many grasses. The rolling of leaves has been shown to reduce transpiration by almost 55 % in semi conditions and by 75 % in desert xerophytes.

6. Leaf surface: - Various morphological characteristics of leaves reduce the transpiration rate and may affect survival of plants drought conditions. Leaves with thick cuticle waxy surface and the presence of spines etc. are common and effective. The leaf surface becomes waxy forming thick cuticle and develops spines on leaves which help in reducing transpiration losses. eg. Safflower.

7. Stomatal frequency and location: - A smaller number of stomata retard the development of water deficits. Location of stomata in cavity or in depressions of leaves reduces the direct contact of stomata with wind currents & reduces the transpiration losses. In drought resistant plants, the number of stomata found more a lower leaf surface. Similarly, the number of stomata is also reduced which helps in reducing transpiration losses.

8. Effect of awns: - Awned varieties of wheat predominate in the drier and warmer regions and have been found to yield better than awnless especially under drought conditions though there are exceptions. The Awned varieties of wheat barley etc. can thrive well under stress conditions as the awns contain chloroplasts & stomata & can continue photosynthetic activities even when the stomata on leaves get closed during day time.

B) To Improving water uptake:-

1. Efficient root system:- The root systems of drought resistant plants are characterized by wide variety of apparent adaptations. These responded to such predominant soil conditions as the duration of soil dryness and the depth that is normally wet. Plants become adapted to dry conditions mainly by developing an extensive root system rather that structural modification of the roots. The "extensive root system" includes additional growth of secondary hair roots.

- **i)** Extensive root system
- **ii)** Deeper root system
- **iii)** Secondary root etc.
- **iv)** Ability of roots to go towards available water
- **v)** Ability of roots to penetrate in soil

2. High root to top ratio (R/T):-A high root to top ratio is very effective mean to adoption of plants to dry conditions of the growth rate of the roots considerably exceeds that of the shoots. The transpiring surface is there by reduced while root system of the individual plant obtains it's water from a large volume of soil (Simonis 1992) has shown that an increased root top ratio may actually result in greater amount of total dry matter of plants grown under dry conditions as compared a similar ones grown with full moisture.

1. Transpiring surface is reduced.

2. Water absorbing surface is increased.

3. High osmotic pressure: Under stress conditions the osmotic (Low osmotic potential) potential in roots and above ground plant parts in reduced resulting increased water movement through soil and plant.

3. High root to root tip ratio:

4. Difference in osmotic potential of plants: - Levitt (1958) has calculated a difference of 0.5% in soil moisture content that includes per manual wilting could supply a plant with enough water to keep it alive for 6 days. This could mean in certain cases the difference between survival and death.

5. Conservation of water spenders to water stress: - Because of increased water absorption water spenders are characterized by very high rate transpiration. However as soon as the absorption rate becomes insufficient to keep up with water loss the water spenders generally develop some of the characteristics of the water savers

Drought tolerance:-When plant is actually submitted to low water potential it can show drought tolerance by either mitigating the actual stress induced by the moisture deficiencies or by showing high degree of tolerance to stresses.

Mitigating stress: - Adoptions a drought basis mitigating effects of stress permit the plant to maintain a high internal water potential inspite of drought conditions. They therefore able to maintain cell turgur and growth avoid direct or indirect metabolic injury due to dehydration

High degree tolerance; Resistance to dehydration:-The simplest method of avoiding drought induced damage is by resisting dehydration, preferably to the extent .of maintaining turgur and at least by avoiding cell collapse after loss of turgur retain their turgur and therefore can continue to grow when exposed to drought stress. When plants are grown in their natural environment their osmotic potentials tend to be characteristic for each ecological group.

Nature of varieties suitable for Rainfed farming:

1. Varieties should have medium height with early grand growth period. e.g. rabi sorghum varieties - Selection - 3. SFV - 86, M -35 - 1.
2. Varieties should have medium tillering habit, bigger ear head size & bold grain size. E.g. bajara variety - shraddha.
3. The variety should have deep and extensive root system.
4. The variety should be of shorter duration.
5. The variety should have High Harvest Index.
6. The intercrop varieties should be of longer duration with differentiation growth habit. E.g. Red gram varieties BDN - 2, No. 148.
7. Varieties should be resistant to moisture stress.
8. Varieties should have coating either with wax or other material which prevent the loss of moisture through evaporation from stem and leaves. E.g. Rabi sorghum varieties - white glumes on stem & leaf sheath. Safflower varieties - waxy surface & spines on leaves.
9. The varieties should be photo and thermo insensitive e.g. Gr. nut variety - TAG - 24.

EFFECTS OF DROUGHT OR MOISTURE STRESS ON THE PLANTS

1) **Water relation**: Water deficits cause several changes in the plants. It alters the water status by its influence on absorption, translocation and transpiration. Moisture stressed plants manifest typical reduction in leaf water potential and relative water content. With the onset of dry conditions, a progressive and continuous decline in turgor of the plants is observed. Water deficits also cause increase in leaf and canopy temperature.
2) **Photosynthesis:** Photosynthesis is reduced by moisture stress. Due to reduction in photosynthesis rate, chlorophyll content, leaf area and increase in assimilate saturation in leaves takes place.
3) **Leaf area:** The reduction in functional leaf area may be due to breakdown of chlorophyll, reduction of leaf expansion, tailoring or branching and increases in leaf senescence in moisture stressed plants.
4) **Assimilate saturation:** Translocation of assimilates is affected by water stress. Due to assimilate saturation, photosynthesis is reduced.
5) **Respiration:** Respiration increases with mild stress. However as the water deficits become sever, it decreases. More severe drought lowers water content and respiration.

6) **Anatomical changes:** Periodical water stress leads to anatomical changes like decrease in size of the cells and intercellular spaces, thicker cell wall and greater development of mechanical tissue.
7) **Metabolic reaction:** Almost all metabolic reactions are affected by water deficits. Severe drought causes decreases in osmotic activity. Accumulation of sugars and amino acids takes place under moisture stress. Proline, amino acid, accumulates whenever there is moisture stress. Accumulation of proline is more in later stages of plants and it is considered as a good indicator of moisture stress. Drought causes alteration of physiological land biochemical metabolism in plants.
8) **Hormonal relationships**: As a consequence of water deficits, hormonal balance is altered. The activity of growth promoting hormones like cytokinin, gibberellic acid and indol acetic acid decrease and growth regulating harmone like abscisic acid, ethylene, betain etc. increases. Translocation of growth promoting hormones is also reduced by moisture stress. Abscise acid acts as water deficit sensor to minimize the loss of tissue water potential. Ethylene is considered to be the cause for leaf and fruit drop. Beaten is used as an indicator of moisture stress.
9) **Protoplasmic dehydrating**: As the tissues become desiccated protoplasm becomes increasingly dense and its viscosity gradually increases. When dehydration is severs, it becomes rigid and brittle.
10) **Nutrition:** Moisture stress affects fixation, uptake and assimilation of nitrogen. Nitrogen fixation by leguminous plants is reduced by moisture stress due to reduction in haemoglobin in nodules, specific nodule activity and number of nodules. Moisture stress may or may not reduce nutrient content, but reduces dry matter production considerably. As a result, nutrient uptake is reduced. Nitrogen assimilation is also affected by moisture stress mainly due to the reduction in nitrate activity.
11) **Growth**: The expansion of cell and cell division are reduced due to moisture stress resulting in decrease in growth of leaves stems and fruits. Moisture stress affects germination, leaf area, leaf expansion and root development. Drought causes weakening or destruction of established crops.
12) **Development:** In general moisture stress delays maturity. However the development response of plants to moisture stress depends on stage of occurrence of stress. The general rule is that if stress occurs before flowering, the duration of the crop increases and when it occurs after flowering, the duration decreases. Drought causes predisposition of crops to insects and diseases.
13) **Reproduction and grain growth**: Moisture regime during flowering and grain development determines the number of fruits and individual grain weight respectively. During ripening, which involves dehydration and certain biochemical processes, moisture regime has very little effect on yield components. Panicale is mostly affected by stress due to reduction in cell expansion., Moisture stress at anthesis causes drying of pollen and loss of viability of pollen.
14) **Yield;** Drought causes reduction in productivity which is brought about by delay or prevention of crop establishments. It also causes alteration of the quality of the grain, forage, fiber, oil and other sorts of products,.

Effect of drought in general:-

1. Depletion soil moisture.
2. Lowering of ground water table.
3. Reduction in Agril. Production.

4. Reduction in industrial production.
5. Reduction in power generation.
6. Adverse effect of established economy

STRATEGIES TO MITIGATE THE DROUGHT

A. Farm level : The agricultural drought is generally managed by adopting following measures.

1. Preventing and recycling of excess runoff.
2. Deep tillage to absorb and hold maximum moisture.
3. Timely weed management to control water loss by ET.
4. Planning for suitable cropping system.
5. Selection of short duration and drought tolerant crops, with low water requirement e.g. castor, sunflower, sorghum, pearl millet.
6. Adjusting sowing time so as to escape the growth, reproductive stage from the high probability period of drought.
7. Management of various inputs to over come the drought situation.
8. Conserving the soil moisture by agronomic practices like mulching, use of antitranspirants to reduce ET.
9. Provision of supplemental irrigation from recycled water ever possible.
10. Reduction in plant population thinning of foliage to reduce ET.

B. Govt. level :- It is recognized that country has to be prepared to face the change of an aberrant monsoon in feature. At present, approximately 28% of the cultivable land is irrigated; the upper limit is 50% of the country. Therefore, the problems of drought prone areas have to be tackled on a long-term basis to minimize adverse effects of drought such a programme includes the following.

1. An early forecast of monsoon to enable farmers to be prepared for a good, normal or bad season.
2. Improved communication systems.
3. Availability of resources such as credit, fertilizers, pesticides and power for increasing production.
4. Proper assistance to farmers in the years when monsoon fails.
5. Adequate prices for produce in good year.
6. Building reasonable buffer stocks for food grains.
7. An improved transportation system
8. Crop insurance

Drought is a hazard to successful production. It occurs due to various combinations of the physical factor of the environment. Internal water stress in crop lands reduces their productivity. This reduction in productivity is brought by

1. Delay or prevention of crop establishment
2. Weakening or distraction of established crops
3. Predisposition of crops to insects & diseases.
4. Predisposition of crops to insects & diseases.
5. Alteration of physiological & bio - logical metabolism in plants & alternation of quality of grain forages fiber etc.

Drought Prone Area:- A drought prone area is defined as one in which "the probability of drought year is greater than 20%

Chronic drought prone area: A chronic drought prone area is defined as one in which the probability of a drought year is greater than 40%.

CROPPING SYSTEM AND CROPPING PATTERN

1. 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,
2. 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 fallow in an area.

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.

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) Monoculture   II) Multiple cropping   III) Fallowing or fallow in Rotation

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) Quadruple cropping
v) Multistoried cropping	ii) Ratoon cropping or Ratooning

I) Monoculture:

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 Rajastan.

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) Some times 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 years 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, Coriander in cereal crops like sorghum .

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 or distinct row arrangement..

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 LERS of the additive series were 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

Sr. No.	Region	Intercropping system	Row ratio
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 fertilizer be applied. For example, in the case of sorghum + red gram intercropping system with 2:2 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 be 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 given as per the requirements 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 before it is ready for harvest e.g. Relay cropping of tobacco in groundnut or relay cropping of *Rabi* sorghum 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) of leguminous shrubs like subabul (*Leucaena leucocephala*) is called alley cropping e.g. growing of maize Jowar, bajara, cow pea etc. in between rows of subabul 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 lopping of the subabul 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 arecanut.

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 gram (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 Marathawada 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
Subhumid soil of chhotananagpur	Maize – Safflower, Rice - Linseed
Subhumid red soil of Orissa	Rice - horse gram
Submontain soils of N.E. Punjab	Maize – mustard Maize-gram
Submontain 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 re-growth after harvest is known as ratoon cropping. Ratooning is one of the important systems of intensive cropping, which implies more than one harvest form the 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 and 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 harrowings. 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 system.

<u>INTER CROPPING</u>- It is practice of sowing of two or more number of crops simultaneously on same piece of land with geometrical relationship.

- series of intercropping based on population are-

i) **Aditive series-** in which maintain the population of base crop as we maintain in sole crop as 100% and additional population of intercrop i.e. 75% ,therefore LER and yield are more than replacement series. This series used in India.

ii) **Replacement series-** in this series scarifying the population of one of component and introduce the intercrop, thereby reduce the plant population This series used in western country.

Advantages- 1) most suitable in Kharif season
2) Efficient use of recourses.
3) best use of land
4) Maintain fertility of soil
5) Complementary effect of crops

Disadvantages- 1) some time difficult for sowing
2) It is not suitable during rabi.

Important requirements of successful intercropping:

1.The time of peak nutrient demand component crops should not overlap. In maize + chickpeaintercropping the peak nutrient demand period of chickpea is around 35 days after sowing while it is 50 days for maize.

2.Competition for light should be minimum among the component crops. Complementary should exist between the component crops. The difference in maturity of component crops should be at least 30 days.

Mixed cropping: Mixed cropping of two or more crops simultaneously intermingled without any rowpattern. It is common practice in most of the dry land tracts of India. Seeds of different crops are mixed in certain proportion and sown. The object is to meet the family requirements of cereals, pulses and vegetable. Thus is called as subsistence cropping.

Sequence cropping (crop rotation) : It can be a defied as growing of two or more crops in a sequence on the same piece of land in a farming year. Depending on the number of crops grown in a year it is called as double (2 crops), triple (3 crops), quadruple (4 crops) cropping.

Sequence cropping (Crop rotation) : It can be defined as growing of two or more crops in a sequence on the same piece of land in a farming year. Depending on the number of crops grown in a year it is called as double (2 crops), triple (3 crops), quadruple (4 crops) cropping.

In addition to these systems , relay and ratoon cropping are also in practice. **Relay cropping** refers to sowing of the succeeding crop before harvesting of preceding crop. **Ratoon cropping** or rationing refers to raising a crop with regrowth coming out of roots or stalks harvest of the crop.

WATER HARVESTING OR RUN OFF FARMING

- Collecting and storing of run-off water on soil surface or in soil profile for the subsequent use.

- Collecting and storing water on the surface of the soil for sub-sequent use is known as water harvesting. It is method to induce, collect, store ad conserve local surface run-off of water for agriculture in arid and semiarid regions.

- The process of runoff water collection during peak rainfall periods in srorage tank, farm ponds is called as **water harvesting**. Its further use for crop production is called **runoff farming**

- About 10 - 20 percent of the total rain goes as runoff in medium deep black soils. This also considerable soil loss by way of erosion. The extent of runoff varies with rainfall intensity and its duration land topography soil type and land use pattern. This runoff otherwise going as waste can be collected in suitable water storage structures such as farm ponds and used further for crop production. This technique of collection of runoff water during the period or excess rainfall and its further use for crop production is called "water harvesting" or "Runoff farming".

- In water harvesting the part of land from which the water is received is called "donor area" or "water producing area" or water harvesting area or watershed area or catchments area and the area in which it is used is called as "Recipient area" or crop production area. The donor area generally is not suitable for crop production.

- Rain water harvesting is the collection, storage and recycling of run-off water for irrigation and other uses. The surface run-off water harvesting can be achieved through dugouts ponds, tankas, *khadins* , *havelis*, diversion bunds and roof-top rain water cisterns. Stream flow run-off harvesting is practiced through *nala*-bunding, check- dams, stop dams, percolation tanks/ponds and *nadi.*

- In dry lands agriculture, water harvesting usually denotes the collection of excess run-off in the farm ponds and using it for providing protective irrigation (pre-sowing irrigation or life saving irrigation or irrigation at most critical stage of crop) and percolation ponds and silt-detention tank to recharge the ground water. The most common water harvesting structures are of **embankment ponds** for hilly and rugged terrains and **excavated farm-ponds** for flat topography.

- For efficient use of stored water, it is necessary to consider conveyance of water, time of irrigation, methods of irrigation, quantity of irrigation water applied and selection of crops and cropping systems. Drip and sprinkler methods of irrigation are recommended to minimize wastage of stored water and to bring more area under command. For collection of higher amount of rainfall, under arid region, run-off is induced either by compacting the soil surface or using ground cover of plastic films, rubber and metal sheeting

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 2. Chemical treatment 3. Surface cover	1. Run-off farming 2. Inter plot water harvesting- 3. Micro- catchment 4. Water spreading	1. Dug wells 2. Tanks 4. farm ponds 5. percolation tanks- 6. Inter row water harvesting 7. Broad beds and furrow and farm ponds

I) In areas with 50 to 80 mm annual rainfall

Following practice were fallowed to induce runoff in extreme arid region to collect water for households and cattle etc.

1. **Land alteration**: Compacting soil surface to increases runoff for higher collection of water.
2. **Chemical treatment**: The material like silicon, latexes, asphalts and wax were used to fill the pores or make soil repellant to water to induce runoff
3. **Surface cover:** Cover like galvanized sheet, butyl rubber cover and low density polythene sheet were used to induce runoff.

II) <u>Arid region-</u>

1) **Run-off farming-**. Watersheds are divided in small catchments area of 1-3 ha on hill side. Through channels uncontrollable water supply to the field.
2) **Water spreading-** During rainy period natural water course diverted to the surrounded plain field
3) **Microcatchmant-**Catchment basins is built in low lying area around the plant with height of 15 cm, depth of basin 40cm. this basin used to collect the run-off
4) **Inter plot water harvesting-** In scanty rainfall area part of field used to collect run-off as a doner area (sloping area) and other part as a receiver area (leveled area) used to cultivate crops.Collected run-off water used to irrigate the crop. The ratio of doner to receiver area is maintained 1:1 or 2:1

III) Semi-arid region:

1) Dug wells- used to collect and store underground water during excessive rainfall and lift for irrigation.

2) Tanks- Run-off from hill sides and forest is collected in tanks. About 50% run-off is collected. Where well and canal irrigation is not feasible due to topography in such situation this method is feasible.

3) Farm ponds- Farm ponds are small storage structure for collecting and storing runoff water. Types 1. Excavated pond for flat topography 2. Embankment ponds for hill area 3. Excavated-cum-embankment ponds.

- Major problem of seepage losses
- control by lining walls with traditional methods by use of bentonite, soil dispersants and soil cement mixture.

4) Percolation tanks- Constructed across the water course and big gallies and water is ponded with the object of charge of water table. Increase the water table encourage to dug the wells for irrigation purpose.

5) Inter row water harvesting- some time higher the rainfall creating water logged condition due to which yield is affected, in such cases, formation of beds and furrow is beneficial. Plantation of maize on bed and rice in furrow helps in increasing the yield of both crops.

Excess water collected in furrow which is beneficial for rice. There may not be enough rain to support a crop in some areas & therefore by conserving more water in furrows and planting the crop in furrows may give some yields.

6) Broad beds and furrow and farm ponds-

- seed bed is made into wide beds of 120-180 cm alternated with furrow width of 45 cm
- This method suit for black soils combined with dry sowing
- excess water collected through grassed water ways into farm pond, and said water used as a protective irrigation.

Techniques of Water Harvesting

i) Inter plot water harvesting: - In this method harvested water is directed to the crop. This method is suitable for area where rainfall is scanty (< 500 mm) and even there is difficulty of maturing a single crop. In this technique a portion of the area is cultivated & remaining area is used for harvesting water. Usually the uncultivated area is compacted or treated in such a way that runoff would be induced. Surface modification may be required to get runoff. Such method is suitable for arid regions. Runoff may be induced by using cover films (plastic or rubber) preparing hydrophobic layer (wax) compacting surface or spreading sodic soil on surface.

ii) Inter row water harvesting: - There may not be enough rain to support a crop in some areas & therefore by conserving more water in furrows and planting the crop in furrows may give some yields.

iii) Water harvesting in farm Ponds: - A portion of the excess runoff water after allowing maximum in situ moisture conservation is collected in farm ponds. As far as possible the pond should be located in the lower patches of the field to facilitate better storage and less seepage losses. The size of the farm pond should be worked out considering annual rainfall probable runoff and the catchments area. Generally, 10 to 20 per cent of the seasonal rainfall is considered as runoff in medium and deep black soils. A farm pond of 150 m3 capacity with side slopes of 1.5: 1 is sufficient for each hectare of catchments area in black soils. The farm ponds may be circular, squared or rectangular. However, rectangular ponds are more convenient for harvesting of runoff water.

Under low rainfall situations to increase the runoff from catchments area the soil surface is treated with sodium salt, betonies clay, hydrophobic compounds like sodium ciliolate, sodium rosinate etc. asphalt bitumen and water proofing membranes like paraffin. Some mechanical measures to increase runoff can be adopted such as land surface smoothening reducing surface depressions compacting the soil surface by rollers of spreading the clay blanket before rolling in sandy soils.

There are three important stages involved in water harvesting.

1. Collection of water in form pond.
2. Storage of water & problems
3. Applications of stored water to the crops.

1. Collection of water in form pond: - From the parameters like annual rainfall, probable runoff and area of catchments the size of the farm pond can be work out. The location of the farm pond should be such that there should be proper storage and facilities to utilize stored water for crop production e.g. if farm is located in rocky and porous part, it would difficult to use stored water for crop production. As for as possible pond should be located in lower patches of the field to facility better storage and seepage losses. The size of the farm pond should be decided by the quantum of water to be stored and nature of the soil strata. If the stratum is hard, rocky then it would be desirable to have shallow pond. If the structure is clay soil in that case depth may be increased and surface area may be reduced to have minimum evaporation. If the pond is located in upper patches water can be create problems or water logging in low lying areas if proper care is not taken.

2. **Storage of water problems**: - Seepage and evaporation losses of stored water are the major problems of farm ponds. Nearly 40 to 50% quantity of stored water is lost through seepage and evaporation. When the pond is with murrum strata the total losses can be to the extent of 72% out at which 80% losses are due to seepage alone. In general the seepage losses in deep black soils are low. For preventing the seepage losses in farm ponds located in coarse textured soils, the sealing materials such as natural clay, soil + cement mixture, stones or brick in cement mortar, asphalt compounds, polyethylene / rubber sheets or plastering with soil + cowdung, etc. can be used for lining the pond surfaces depending upon the easy availability and cost of the material. However compacting and lining with natural clay soil is most economical.

The evaporation losses from free water surface can be reduced by spreading the materials on water surface such as plant residues, oil emulsions, long chain fatty alcohols i.e. Cetyl alcohol, polyethylene oxides. Floating blocks of wax rubber and plastic floats are more effective in controlling the evaporation to the extent of 80 percent.

3. Application of stored water to the crops: - Since available water in the farm pond is a scare commodity, its optimum use is the important consideration in entire runoff farming. In the case of application of water for crop production, two considerations need to be borne in mind. First is the method of application and second the stage of crop growth.
For efficient application furrow irrigation or alternate furrow irrigation methods should be used than surface irrigation which will increase water use efficiency of stored water. When the stored water is to be used for post rainy season (Rabi) crops the water should be applied at the most critical growth stages. For example: Rabi sorghum - When 2 irrigations are to be applied First - stem elongation stage - 30 - 35 DAS. Second - Flowering 65 - 70 Days. When stored water is limited and only one irrigation is possible in that case water may be applied before flowering.

The research findings from Solapur have indicated that grain yields of Rabi sorghum, safflower and gram can be increased by 100, 40 & 60% respectively by applying single irrigation at boot stage, rosette stage & pod development stage respectively to above crops.

MANAGEMENT OF RAINFED CROPS

Dryland constitutes about 75 per cent of cultivatable lands in the country. The contribute about 42 per cent of of grains, almost all the coarse grains and 75 percent pulses and oilseeds. More than 90% of sorghum, Pearl millet, groundnut and pulses are grown in arid and semi arid areas.

At present, the cultivable area under Dryland agriculture in the state is 87% and only 13% area is under irrigation. After harvesting all available water resources, it is possible to bring it to 30%. It means 70% of the cultivable area will remain as Rainfed in the state. Under this situation the state will have to depend upon for its major share of food production on Dryland. However, the Dryland agriculture suffers from two problems viz. low productivity and high in stability.

The reasons for low productivity in Rainfed area are:

1. Lack of moisture conservation practices.
2. Low rate of fertilizer use.
3. Lack of timely farm operations.
4. Improper crop planning as per land capability.
5. Inadequate efforts to increase water resources.
6. Unpredictable rainfall situations.
7. Lack of improved Technology

The adoption of improved Dryland technology will be the only answer to mitigate above situation. Considerable research efforts are being made in the state to develop the improved the improved Dryland technologies since early seventies which will help to improve the crop production in Rainfed agriculture.

Various agronomic and other experiments were conducted at Solapur and other research stations and on cultivators field which have generated good information useful for the farmer in rainfed lands. The farmers are interested in knowing these package of practices which they could adopt promising information obtained from the experiments was used to formulate the package of practices under the name 'Improved dry farming technology' for crop production.

Continuous research on rainfed agriculture is going on at Dry Farming Research Station, Solapur since 1933. It is rather difficult to draw the conclusions on the research carried put, due to varying types of soil, rainfall and climatic conditions. The package of practices evolved under dryland is as below.

1. Deep tillage once in three to five years
2. Use of organic manures
3. Time of sowing
4. Use of two bowl seed drill
5. Intercropping Double cropping
6. Alternate land use
7. Use of fertilizers
8. Use of improved varieties and seed treatment.
9. Optimum plant populations.
10. Plant protection and weed management
11. Protective irrigation during soil-moisture stress at critical growth stages
12. Growing of sorghum as a sole crop in *rabi*.
13. Farm ponds for runoff harvesting and recycling.
14. Proper land use planning applicability.
15. Land cover
16. Vertical mulch.
17. Cropping pattern
18. Mid-season correction practices.

19. Soil and water conservation practices.
20. Crop planning for aberrant weather situations.
21. Integrated weed management.
22. In-situ moisture conservation.
23. Integrated nutrient management.

The important improved Dryland technologies are given below:

1. Selection of efficient crops and their varieties:
2. Crop planning as per length of cropping season:
3. Developing suitable varieties for dry lands.
4. Seeding time for Dryland crops
5. Timely seeding for pest avoidance
6. Planting pattern and plant densities
7. Intercropping
8. Fertilizer use in Dryland
9. Weed Management
10. Use of minimal irrigation
11. Crop planning as per land use capability
12. Crop planning for aberrant weather situation in dry lands
13. mid - season correction practices
14. Soil and water conservation practices

1. Selection of efficient crops and their varieties:

Improved varieties and hybrids of Kharif and Rabi crops have higher moisture use efficiency as compared to local varieties. Hence improved varieties are adopted for efficient moisture use.

Kharif crops:

Bajara - Shraddha (RHRBH - 8609, Saburi (RHRBH - 9824) **Sunflower** - Modern, SS- 56, EC - 68414, KBSH - 11, APSH - 11). **Gr. Nut** - SB X 1, K - 4 - 11, ICGS - 11, TG - 26, Koyana (B - 95). **Red gram** - No. 148, BDN - 2, ICPL - 87; TT - 6, T - Vishakha - 1. **Cowpea** - Konkan Sada bahar. **Soybean** - MACS - 13 Pk - 472, Monetta, JS - 335. **Setaria** - Arjun . **Horse gram** - Sina, Man (Kulthi or Hulga). **Green gram** - PM - 2, S-8, Jalgaon - 781, BM - 4, THRM - 18. **Black gram** - T - 9 TPU - 4, TAU - 1, TAU - 2. **Castor** - Aruna, VL - 9, Girija . **Kidneybean** - MBS - 27 (Matki), **Grasses - Marvel** - 8; Stylo, Siratro.

In general, the use of improved varieties increases the grain yields by 20 to 25 percent over local varieties. Hence sowing of these varieties should be carried out in Rainfed Agriculture.

Rabi Crops:

Rabi sorghum - M - 35 - 1 (Maldandi), Selection - 3, Swati (SPV - 504), CSV - 14 - R.
Gram - PG - 12, Vijay, Vishal, N - 59, Chaffa, Bharati, **Safflower** - Bhima, Girana

2) Crop planning as per length of cropping season:

A) Cropping season with less than 20 weeks: Single crop either in Kharif or Rabi. **Kharif -** Bajara, Green gram, Gr. nut, black gram sunflower. **Rabi** - Jowar, Safflower, gram.

B) Cropping season with more that 30 weeks: Two crops with short duration Kharif crops following by 100 - 120 days rabi crops. E.g. Bajra / Green gram - R. Jowar, Safflower, Gram.

C**) Cropping season with 20 - 30 weeks:**
Suitable for intercropping e.g. Pearl millet + Red gram (2: 1)

3. Developing Suitable Varieties For Dry Lands
The varieties or hybrids suitable for dry lands should have flowing characteristics.

i) Short duration, medium height, high yielding ability.
ii) Big ear head size with bold grains.
iii) Resistant to water stress conditions.
iv) Strong penetrating root system.
v) High Harvest Index
Eg. Grunt JL - 24, TAG - 24, Bajra - Shraddha - Safflower - Bhima
Horse gram - Sina, Man etc.

4. Seeding time for dryland crops: Proper time of seeding is important in dry lands as the let growing season is likely to be shortened. For this rainfall probabilities. Eg. Cotton, red gram, horse gram dry seeding in 24th Meteorologist week at Solapur found optimum. For this the off season tillage to be practiced to shorten the time aces between first rain and actual seeding time. It also helps to increases moisture. Timely seeding of Rabi crops is also important eg. Sorgurti & Safflower - Traditional practice - end of September. Improved practice - first fortnight of September. This helps in better utilize of soil moisture and nutrients.
5. Timely seeding for pest avoidance:Timely seeding of Kharif crops found useful in avoiding cest incidence. E.g. Kharif sorghum should be sown before early. July to seed shoofly incidence at seeding stage and midge fly incidence at flowering to grain formation stage.
6. Planting pattern and plant densities: Under adequate soil moisture conditions change in planting pattern has no advantage. However, it is necessary while adopting intercropping systems to accommodate intercrop rows. E.g. Kharif - Bajra + Tur in paired planting in 2: 1 row proportion (30 - 15cm.). Under limited soil moisture paired planting is useful during the season for efficient moisture paired planting is useful during Rabi season by efficient moisture use. E.g. Rabi sorghum 30 - 30 - 60 cm. or 45 - 45 - 90 cm spacing. This is due to deeper & more root growth and convenience in inter culture operations. Plant density - While deciding the plant density, the availability of stored soil moisture needs to be considered. Gram - Low soil moisture - wider planting - 60cm. high soil moisture - closer planting - 30 cm. Sorghum - Low soil moisture - 5 - 10 plants / M2.High soil moisture - 5 -10 plants / m2.Safflower - Not affected by plant density. Bajra - 10 - 15 plants / m2 optimum. Safflower - 1 to 1.25 Lakhs plants / ha optimum. The optimum plant population leads to higher production per unit area.

Sr.No.	Crop	Spacing (Cm)	Plant population in lakhs / ha
1.	Bajra	45 x 15	1.5
2.	Groundnut	30 x 15	2.5
3.	Red gram	60 x 20	0.75
4.	Horse gram	30 x 10	3.30
5.	Moth bean	30 x 10	3.30
6.	Setaria	30 x 5	6.0
7.	Sunflower	60 x 20	1 to 1.25
8.	Gram	30 x 10	3.3

Developing suitable varieties for dry lands, Seeding time for dryland crops, timely seeding for pest avoidance and Planting pattern and plant densities

7. Intercropping: Mixed cropping is traditionally adopted in rained areas for risk distribution during adverse weather conditions there by achieving yield stability. Now the mixed cropping has changed to intercropping due to substantial research efforts. The intercropping has proved substantial yield advantage over sole crop. It also gives greater stability of yields over different seasons. The intercropping is more popular among the small farmers to meet their need for different crops. The intercropping is more advantageous during Kharif than rabi season.

Points to be considered while selecting crops for intercropping:

i) Both the crops should have differential growth habit

ii) They should have different crop growth period.

iii) There should be more competition tree period between these two crops.

iv) They should have differential requirements interspect at nutrients and soil moisture.

v) They should have different feeding zones.

vi) Mostly there should be a combination of cereal and legume.

Eg .Bajra + Tur - 2:1 proportion . Cotton + green gram - 2: 1 proportion. Sorghum + green gram 2: 1 proportion, Sunflower + Tur - 2: 1 proportion , Sorghum + Tur 2: 1 proportion

8. Fertilizer use in dryland: Fertilizer use is an important factor for increasing the yield of dryland crops. The soils of dryland are low in N low to medium in P and rich in available K. The research breeds out in fertilizer use of various crops have suggested ad definite response to fertilize, application. The fertilizer application not only increase are yield of dry land crops but also enhance the growth and maturity of the crops.

The time and method of application of fertilizer are also important because of moisture limitation of dryland. The fertilizer should be applied at the time of sowing by placement method. For this purpose, Solapur centre has developed two bowl ferti seed drill which now become more popular among the farmers.

The response top application to deep black soils is limited the to high p fixation due to calcium content. For Rabi crops advance placement of p by 10 - 20 days before actual sowing is usual practice. The soils of dryland are medium to rich in available K and hence no responce to K application. Under light textured soils boron application @ 5 kg Borax x / ha at in alternate years to groundnut is recommended for dry lands of Maharashtra. Under intercropping systems, there is no need to apply additional utilizes to intercrop of legume under cereal + legume combination. Under sequence cropping under dry lands, when cereal is grown after gumes like green gram, black gram, the N application may be reduced by 5 to 30 kg N / ha to cereal or oil seed crops like sorghum sunflower of safflower.

9. Weed Management: It is estimated that weed cause about 37 to 79% pass to the crop production in dryland agriculture where moisture is the most limiting factor. The research findings on weed - crop competition in Dryland indicated that in crops with 80 to 120 days duration first 20 to 30 lays period is more sensitive to competition from weeds. Checking weed growth during this period helps in to minimize the loss in crop production. The results with perarlmillet at Solapur confirm the above observations.

Weed control through chemicals: Chemicals are found to be as effective as mechanical measures in controlling the weeds in dryland agriculture. Use of Atrazine @ 0.5 to 1.0 kg a.i. / ha as pre-emergence for cereal crop is effective. The weeds like striga can be controlled effectively by 2, 4 - D from mechanical measures.

Integrated weed control: A combination of mechanical and chemical weed control methods are most effective. Studies carried out at Solapur on methods are most effective. Studies carried out at Solapur on Kharif groundnut showed that combination of pre - emergence spray of Propanil @ 3 kg/ha + weeding at 30 days after sowing increased yield of groundnut by 100 per cent. Use of Basaline ! 1 kg/ha + one hand weeding at 30 DAS has also found effective at other locations.

Off season tillage for weed control : Off season tillage would control the weeds reaching maturity after the harvest of first crop and checking multiplication. It also helps in timely sowing of crop with first shower of rain.

10. Use of minimal irrigation: Moisture due to low rainfall and limited soil moisture due to soil depth are the situations normally experienced in dryland agriculture. Mid season droughts and soil moisture deficiency could be mitigated by applying protective irrigations to the crops alermn growth stages. The harvested water in farm ponds or from seam functioning wells can be utilized for the purpose. Research current Solapur has indicated that the grain yields of Rabi Jowar, Safflows a gram can be increased by 100, 40 - and 60% respective by arrive single irrigation at most critical growth stages. For this, the irrigation should be applied at boot stage rosette stage and pod development stage to jawar, safflower and gram respectively.

11. Crop planning as per land use capability: The cultivable land in wear has different depths ranging from few cm to several meters. Available so moisture depends on the soil depth. The water requirement of different crops varies from crop to crop. Therefore, crop planning as per vate storage capacity of the soil helps in increasing and stabilizing crop avoid with higher economic returns. Following crop planning is suggested to dryland farming in Maharashtra for different soil depths.

Soil type	**Soil depth (cm)**	**ASM (mm)**	**Crop planning**
1. Very shallow	<7.5	15.2	Dry land horticultural crops, grasses
2. Shallow	7.5 to 22.5	30 - 35	Horse gram, Kidney bean, castor,
			grasses, agro - forestry, dryland
			Horticultural crops. Bajra + Matki
3. Medium deep	22.5 to 45	40 - 65	Pearl millet, Red gram, sunflower
			groundnut, Castor, Pearl millet +
			Red gram (2 : 1), Sunflower & Red gum
			(2: 1) intercropping systems.
4. Medium deep	45 to 60	65 - 90	Rabi jawar, sunflower, safflower, gram
			Pearl millet + Red gram (2 : 1) in
			Intercropping systems.
5. Medium deep	60 to 90	90 - 150	Double cropping Kharif green gram back
			gram, Rabi sorghum, safflower or Sade
			crops in rabi i.e. sorghum safflower and
			Gram.
6. Deep	> 90	> 150	As above

Important components of improved Technology:

A) *Kharif Crops*

	Component	**Pearl-millet**	**Green gram**	**Red gram**
1.	Time of sowing	Upto mid July depending on rains	Upto mid July depending on rains	Upto mid July depending on rains.
2.	Improved variety	Shardha, Saburi ICTP -8203 Shanti-RHRBH-9808 Sambrudhi	Kopargaon,J-781PM - 2 BM-4.T.A.R.M-18 PM-9339(vaibhav)	BDN-l.BDN-2, ICPL-87, ICP-87119.AKT-8811 BSMR-736, Vipula, BSMR-853

3.	Row spacing (cm)	45 x 15	30 x 10	60 x 20
4.	Plant population	1,50,000	3,30,000	74,000
5.	Seed rate kg/ha	3 to 4	15 to 20	15 to 25
6.	Fertilizers kg/ha a)N b)P2Os	 60 (Two doses) 30	 25 (at sowing) 50	 25 (At sowing) 50
7.	Moisture Conservation Practices	Timely hoeing and weeding, optimum plant population.	Timely hoeing and weeding, optimum plant population.	Timely hoeing and weeding, optimum plant population.
8.	Plant protection	Dusting of methyl parathion dust 2 % @ 20 kg/ha	Dusting of methyl parathion dust 2 % @ 20 kg/ha	Dusting of methyl parathion dust2%@ 20 kg/ha
9.	Special treatment	Clean cultivation up to 20-30 days from sowing	*Rhizobium* culture seed treatment before sowing	*Rhizobium* culture seed treatment before sowing.

B. *Rabi* Crops:-

	Component	*Rabi* Sorghum	Saffower	Gram
1	Time of sowing	First fortnight of September preferably first week.	First fortnight of September preferably first week.	Second fortnigh of September.
2	Improved variety	M-35-1, CSH-14-R, CSH-13-R, Swati (SPV-504), SPV-839 Section -3 Phule Yashoda Mauli, Phule chitra, Phule Vasuda	Bhima, Girana and Sharda, Phule Kusuma,	Vishvas,PG-12, Vijay, Vishal, Sweta, Barati, Virat., digvijay
3	Row spacing (cm)	45 X 15 (medium) 45 X 20 (Light soil)	45 X 20	30 X 10
4	Plant population	1,10,000	1,10,000	3,30,000
5	Seed rate kg/ha	10	10 to 12	60 to 100 kg/ha as per variety
6	Moisture conservation Practices:- Timely thinning, weeding hoeing and use of Mulches etc.			
7	Fertilizers kg/ha a)N b)P_2O_5	 50 25	 50(At sowing) 35	 25 (At sowing) 50
8	Plant protection	i) Seed treatment with Carbosulphuran 25 STD 5% before sowing. ii) Seed pre treatment with sulphur @ 3-4 g/kg before sowing	Dusting of 2% methyl parathion for aphids at pre flowering stage	Dusting of 2% methyl parathion for pod borer during pod formation
9	Special treatment	Use of mulches	Timely hoeing for moisture conservation	*Rhizobium* culture treatment before sowing.

Different varieties recommended for *Kharif* season in drought prone area.

Sr. No.	Crop	Variety	Duration (days)	Yields (q/ha)	Remarks
1.	Bajara	A) Shradha (RHRBH-8609)	75-80	25-30	Under favourable condition gives 5o to 70 a/ha grain yield.
		B) Saburi (RHRBH-8924)	75-78	30	Under favourable condition given 40 to 62 a/ha grain yield.
		C) ICTP-8924	70-80	20-22	1 to 2 tillers, resistant to yellow mosaic.
2.	Setaria (Rala)	ISC-279 Arjun	85-90 80-90	21 19	
3.	Red gram	BDN-1	155-165	16-18	Red, Big size grain, resistant to wilt and suitable for intercropping
		BDN-2	155-165	16-18	White, medium size gram, Resistant to wilt. Suitable for intercropping
		ICPL-87	120-125	15-16	Early variety, suitable for double cropping.
		ICPL-87119	180-200	15-16	Red, Big size grain Straight and suitable for *Kharif* and *rabi* cropping.
		AKT-8811	130-140	15-16	Medium straight variety suitable for double cropping.
4.	Green Gram	Kopargaon	60-65	8-19	Green, big size grain
		J-781	65-70	8-10	Green and big size grain
		Phule-M-2	60-65	11-12	Medium, green colour suitable for *Kharif* and summer
		BM-4	60-65	10-12	Medium, green colour suitable for *Kharif* and summer
		TARM-18	65-70	10-12	Resistant to Downy Mildew
		Phule mug (vaibhav) 9339	60-70	11-12	40% more yield than J-781
5.	Black Gram	TPU-4	70-75	11-12	Medium grain
		TPU-1	70-75	10-11	Big size black grain
		TAU-2	65-70	10-12	Short variety, suitable for heavy soil.
6	Horse Gram (Kulthi)	Sinna	115-120	8-9	Medium white grain.
		Man	100-105	7-8	Dark gray colour grain Early variety.
7.	Kidney bean	MBS-27	125-130	7-8	Resistant to yellow mosaic.
8.	Ground Nut	JL-24	90-95	18-20	*Kharif*
		SB-XI	105-110	12-14	Summer and *Kharif*
			120-1124	15-18	All Maharashtra
		M-13	130-135 145-150	16-17 22-25	*Kharif* *Rabi*
		TMV-10	125-130	20-21	*Kharif*
		TAG-24	100-105	12-14	*Kharif*
			110-120	20-25	*Rabi*
		TG-26	95-100 110-115	15-20 30-32	*Kharif* Summer
		ICGS-11	125-139	26-30	Summer
		Koyana-(B-95)	130-135	25-30	Summer
		Phule Vyas (JL-220)	90-95	20-22	*Kharif*

Sr. No.	Crop	Variety	Duration (days)	Yields (q/ha)	Remarks
9.	Sesamum	Phule Til NO. 1	90-95	5-6	Suitable for all M.S. Jalgaon, Dhule
		Tapi (JLT-7)	80-85	6.0-7.0	Augrangabad, Jalna
		Padma (JLT-26)	72075	6,5-7.5	Jalgaon and Dhule.

Sr. No.	Crop	Variety	Duration (days)	Yields (q/ha)	Remarks
10	Sun-flower	Ec-68414	100-110	10-12	For *Kharif*
		Morden	85-85	7-8	Suitable for light to medium soil.
		SS-56	80-85	8-10	Suitable for drought prone area of M.S.
		KBSH-11	90-100	10-15	Hybrid variety, suitable for all season.
		APSH-11	90-100	10-15	Hybrid variety, suitable for all seasons.
11.	Castor	Girija	110-112	10-14	Suitable for Maharashtra
		VI-9	100-110	11-15	Suitable for Maharashtra
		GAUCH-1	100-110	16-18	Suitable for Maharashtra
		Aruna	115-120	10-12	Suitable for Maharashtra
		GCH-4	210-240	15-20	Suitable for Maharashtra
12.	Soybean	MACS-58	90-100	25-30	
		MACS-124	90-100	25-35	
		JS-335	90-95	25-35	
		PK-1029	95-100	35-40	
		MACS-450	90-95	25-30	
I3	*Rabi* Sorghum	CSH-13R	115-120	25-30	
		CHS-15R	115-120	32-35	
		M-35-1	120-125	15-18	
		Swati	120-125	24-28	
		SPV-839	115-120	20-24	
		Selection-3	105-110	5-6	For light type soil
		Phule Yashoda	120-125	30-32	For medium to heavy soil
		Mauli	105-110	15-20	On medium soil
				8-9	On Light soil
14	Gram	Vishwas	115-120	10-11	Rainfed
				28-30	Irrigated
		Phule-G-12	105-110	12-13	Rainfed
				28-30	Irrigated
		Vijay	85-90	15-16	Rainfed
			105-110	25-40	Irrigated
	Gram	Vishal	110-115	14-15	Rainfed
				30-35	Irrigated
		Shweta	100-105	8-10	Rainfed
				18-20	Irrigated
		Bharti	110-115	14-15	Rainfed
				30-32	Irrigated
		Phule - G (Virat)	110-115	30% More yield than ICCV-2 variety.	
15.	Safflower	Bhima	130-135	14-16	
		Girana	130-135	15-17	
		Sharda	12-124	15-17	

I. Special management practices for heavy rainfall area (1150 mm)

1. Terracing of land having slopes of 10 percent in Western part of Maharashtra.
2. Conversion of heavy soil areas into *dofasli* (double cropping) by compartmental bunding in eastern part of Maharashtra.
3. Construction of small tanks or bodies to impound rain water for protecting the crop whenever long breaks occur at critical growth stages of crops (Paddy).
4. Use of early high yielding varieties of paddy like IR-8, Taichung Native 1 etc. Which will mature within 110-120 days. So that a second crop of legume can be taken on available moisture.
5. Heavy dose of manures and fertilizers.
6. Adoption of green manuring practices and growing crops on bunds.

II. Special Management practices for rainfall receiving 1150 mm to 750 mm areas.

1. Selection of proper land for different crops.
2. Use of early maturity and high yield varieties of crops such as hybrid Jowar, hybrid Bajara, hybrid maize, ground nut and early maturing wheat.
3. Graded bunding to conserve the soil and to drain out excess water.
4. Construction of drains to remove surplus water.
5. Adoption of higher seed rate to have optimum plant population.
6. Heavy dose of manures and fertilizers to improve the soil structure and to supply plant nutrients to high yielding varieties.
7. Growing plant, which provide luxuriant foliage for green manuring and other crops on bunds.

III) Special package of practices for scarcity area (Rainfall 500 mm to 750 mm)

1. Counter bunding to conserve moisture and to check soil erosion.
2. Counter cultivation.
3. Deep ploughing once in three years
4. Use of 6 to 7 tons of FYM/ha. .
5. Lower seed rate and wider spacing to have low plant population/ha.
6. Growing early maturing crops.
7. Fallow strip cropping
8. Rotating cereals and legumes
9. Construction of percolations tanks

PREPARATION OF CONTINGENT CROP PLAN FOR ABBERRANT WEATHER SITUATION

The contingency planning is also known by the term aberrant weather planning or mid-season correction long term historical data on rainfall indicate that the rainfall is seasonal, erratic and highly variable in time and place.

Definition: - The contingency cropping is growing of suitable crop in place of normally sown crop highly profitable crop of the region aberrant weather conditions.

In dry land agriculture, contingency of growing another crop in place of normally growth crop arises due to delay in the onset of monsoon.

Following types of aberration can occur in dry land-farming:-

1. Commencement of rain may be early or considerable delayed
2. There may be prolonged dry spell during south west monsoon.
3. Rain may terminate earlier than normal cessation date or continue beyond normal rainy season.

1. Late on set of Monsoon

Rainfall analysis indicates that in drought prone areas if there is late onset of monsoon in three years out of every 10 years. Crop and varieties recommended for normal monsoon may not be remunerative for delayed sowing due to late onset of monsoon. Transplanting and sowing of alternate crop/variety are the two options under these situations.

Onset of delayed monsoon is a common feature of the dryland agriculture. If the Kharif soils (< 45 cms) are diverted for rabi sorghum under such delayed rains, it not only affect the production of Kharif crops especially pulses and oilseeds but also results in poor production of rabi sorghum. Hence such shallow soils must be put under Kharif crops. Substantial research efforts were made at dryland centre. Solapur in this regards and following cropping pattern has been suggested depending on the lateness of monsoon during Kharif season.

a) Transplanting:- Seedlings are raised in the nursery under irrigation. Transplanting is done after receipts of rains e.g. Bajara, finger millet, Sataria etc.

b) Use of alternate crop/variety: Certain crops and varieties can perform better even if sown late in the season. Crops are to be selected with crop duration to coinside with the length of growing season. Generally short duration pulses may suit the situation. However, if the monsoon turns to be extremely good opportunity of getting good harvest lost if only short duration crops are sown. Economically saved farmers can be to motivated with some risk for sowing long duration crops. Depending on the date of onset of monsoon in dry land situation of Maharashtra following contingent cropping as suggested.

Table: - Contingent crop planning (Mid Season correction)

Rainfall situation	Suggested crops	Remarks
1. Normal onset of Monsoon. Rains during Ist fortnight of July	All Kharif crops Bajra, Setaria, sorghum, grunt, castor, Red gram, Horse gram, Black gram, sunflower	Adopt intercropping of Bajra + red gram in 2 : 1 preparation

2. Late onset of monsoon Rains during 2nd fortnight of July (Rains delayed by 15 days_	Setaria, Sunflower, castor, Red gram, Horse gram (delate Bajra, sorghum, gr. nut, black gram)	Intercropping of Red gram + Setaria in 2 : 2 Proportion.
3. Very late onset of monsoon Rains during Ist fortnight of august (Rains delayed b 7 y 30 days)	Sunflower, red gram, castor, castor, horse gram (delese Setaria from above set)	Intercropping sunflower + Red gram in 2 : 1 proportion
4. Very very late onset of monsoon Rains during 2nd fortnight of august (Rain delayed by 45 days)	Castor, sunflower red gram (Delete horse gram from above set.)	Red gram in 2:1 proportion
5. Extremely late onset of monsoon Rains during Ist week of September (Rains delayed by 50 days)	Rabi jawar for fodder	

2. **Good Start of Monsoon followed by dry spells.**
   This situation is very common. Under these conditions following measures may be adopted for kharif crops.
   i) Controlling plant population for conserving and effective use of available moisture. The reduction of plant population, if it is done during first 30 days, it can increase the grain yield of sunflower by 28% over normal plant population in aberrant weather situation
   ii) Checking weed growth to reduce moisture loss.
   iii) Increasing interculturing operation to prevent evaporation.
   iv) Choice of crops like red gram and castor
   v) Spraying of 2 % urea, Mulching, Protective irrigation, Land configuration for in situ moisture conservation etc.

3. **Early withdrawal of Monsoon:**
   This type of situation is more dangerous in drought prone area. Sowing of *rabi* crops may be suspended. If sowing is not done. In early September, *rabi* crop may be in danger in such type of situation, if sowing of *rabi* crops are done in early September, moisture conservation practices need careful alteration by appropriate practices. Some recommended moisture practices are enlisted below:-

1. **Reduce plant density** *Rabi* crops like sorghum, sunflower, sown early September at 1 to 1.35 lakh/ha. Reduce 50% plant population /ha plant population need to be adjusted before plants go for their grand growth period. Decision making is, however, very important.
2. **Use surface mulch**-moisture can be conserved by using farm waste material @ 5t/ha immediately after emergence of *rabi* crops.
3. **Protective irrigation** - If possible one or two protective irrigation may be given at critical growth stages of crops. If only one protective irrigation is available, it should be given at 55-56 days growth, if severe moisture stress is occurred, the same may be applied at 35-40 days growth. The effect of protective irrigation applied at 40 days after sowing.
4. **Increase frequency of Inter cultivation** to prevent cracking and there by loss of moisture, frequency of Inter cultivation may be increased. Usually 3 inter culturing are recommended (3 hoeing, 3^{rd}, 5^{th} and 8^{th} week after sowing). It the same are increased to 5 to 6, which would

be helpful for creating the dust mulch.

5. **Stripping of leaves**: It helps to control moisture loss temporarily, but it was not bound to be useful practice for prolonged drought.

4. **Extended Monsoon:-**

Extended monsoon may require postponement of sowing of *rabi* crops. Such situation is rarely experienced. Double cropping is possible in medium deep soils. Sowings of *rabi* crops are extended. In such case, replacement of normal crops in certain area would be essential. It is usual experience that extended monsoon results in cool spells, where sorghum may require replacement with sunflower or gram

Dry seeding- It is practice of placing the seed in the dry soil at proper depth with respect to the rains received thereafter. Areas of dependable onset of rainfall are suitable for dry seeding and fertilizer placement. Dry seeding method is suitable for black soil. Sowing peration difficult after onset of rainfall. This practice not suitable for small seeded , as well as, if oil seeds and pulses are not sown deep they are likely to be destroyed by termites and birds. Dry seeding of crop in India like cotton is sown in malwa and Vidarbha region as assured rains..Dry seeding is a very risky proposition in alfisols. The success of dryseeding depends on 1) prediction of onset of monsoon. 2) Seed hardening

WATERSHED MANAGEMENT

Introduction:

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 demand 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.

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

The basic objective of watershed management is thus, meeting the problem of land and water use not in term of any one resource but on the basis that all resources are independent and must, therefore be considered together.

The watershed aim utilizing at improving standard of living of common people of the watershed. By increasing their earning capacity by offering facilities such as electricity, drinking water, irrigation water flood control etc.,

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.
7. To control runoff
8. To control erosion to avoid sedimentation

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: 10 to 100 ha.
v) Milli watershed 1 to 10 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 use of available water through proper field layouts, lands shaping, leveling and lining of water sources and life saving 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 minimise 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 *insitu* moisture conservation and needs remade or renovation every year. Components include improved crops and cropping systems. Which also including 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 drains, 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.

-Crops and varieties to suit length of cropping season,
-Optimum seeding time,
-Fertilizer schedules and balanced use of plant nutrients for crops and cropping systems identified .
-Weed management and package of practices for aberrant weather, and
-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 utilising 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 hydrolic 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.

Basic Information

To start the programme in a systematic way, the following basic information is necessary.

- Statistics of population and livestock,
- Pattern of land ownership,
- Topography, cropping systems and yield, and land capability for farming,
- Data on rainfall, erosion problems and ground water,
- Information on existing water sources like tanks, well etc, and
- Service facilities like schools, banks, input supply, market, health and veterinary facilities etc.

Factors affecting watershed management (runoff factors)

A) Watershed characters

1. Size of watershed
2. Shape of watershed
3. Slope of watershed
4. Orientation of watershed
5. Land use
6. Soil moisture
7. Soil type

8. Topographic characteristics, and
9. Drainage Density.

B) Climatic characteristic

1. Type of precipitation
2. Rainfall intensity
3. Duration of rainfall
4. Rainfall distribution
5. Direction of prevailing wind and
6. Other climatic factors.

Watershed characters

1. Size of watershed: Regarding the size of watershed, if all other factor including depth and intensity of rainfall are being same then two watershed irrespective of their size, will produce about the same amount of runoff .However a large watershed takes longer time for draining the runoff to the outlet as result the peak flow expressed are depth is being smaller and vise versa.

2. Shape of watershed: The shape of watershed has a great effect of runoff. The watershed shape is generally expressed by the terms "farm factor and "compactness coefficient".

3. Slope of watershed: The slope of the watershed has an important role over runoff but its effect is complex. It controls the time of overland flow and time of concentration of rainfall in the drainage channel which provide accumulative effect on resulting peak runoff. For example in case of a sloppy watershed. The time to reach the flow at outlet is less, because of greater runoff velocity which results into formation of peak runoff very soon and vice -versa.

4. Orientation of watershed: This factor affects the evaporation and transpiration losses from the area by making influence on the amount of heat to the received from the sun. The north or south orientation of watershed, affects the time of melting of collected snow. In a mountainous watershed the part of wind ward side of the mountain receives high intensity of rainfall resulting into more runoff yield while the part of watershed towards leeward side has reverse find of the same.

5. Land use: The land use pattern and land management practices used have great effect on the runoff yield. For example an area which is under forest cover, where a thick layer of mulch of leaves and grasses etc. has been accumulated there formed a little surface runoff due to the fact that more rain water is absorbed by the soil. While in a barren field where not any type of cover is available a reverse trend is obtained.

6. Soil Moisture: The magnitude of runoff yield depends on the amount of moisture present in the soil at the time of rainfall. If rain occurs over the soil which has more moisture the infiltration rate becomes very less which results in more runoff yield. Similarly if the rain occurs after a long dry spell of time when the soil is dry, causing to absorb huge amount of rain water. In on the other hand, if the rain occurs in a close succession as in the rainy season; runoff yield has reverse effect.

7. Soil Type: In the watershed surface runoff is greatly influenced by the soil type as loose of water from the soil is very much dependent on infiltration rate which varies with the types of soil.

8. Topographic Characteristics: Topographic characteristics include mores topographical features of watershed which create their effect on runoff it is mainly undulating nature of the reason that runoff water gets additional power to flow due to slope of the surface and altitude time to infiltrate the water into solid. Regarding channel characteristics to describe their effect on runoff the channel cross-section, roughness storage and channel density are mainly considered. These also have significant effect on runoff.

9. Drainage Density: The drainage density is defined as the ratio of the tannedl channel length in the watershed to total watershed areas it is expressed at.

$$\text{Drainage density} = \frac{\text{(Tranned length (Total))}}{\text{Watered area}}$$

$$D.D. = \frac{I}{A}$$

A watershed having greater D.D. and indicates formation of peak run off very shortly to that of lesser D.D. watershed.

B) Climatic characteristic

1. Type of precipitation: Types of precipitation have a great effect on the runoff. For example a precipitation which occurs in form of rainfall, starts immediately in from of surface flow over the land surface, depending upon its intensity as well as magnitude, while a precipitation which takes place in form of snow or hails the flow of water on ground surface will not take place immediately, but after melting of the same. During the time interval of their melting the melted water infiltrates into the soil and results a very little surface runoff generation.

2. Rainfall intensity: The intensity of rainfall has a dominating effect on runoff yield. If rainfall intensity is greater than infiltration rate of the soil the surface runoff takes place very shortly while in case of low intensity rainfall, where is found a reverse trend of the same. Thus high intensities rainfall yield higher runoff and vice-versa.

3. Duration of rainfall : Rainfall duration is directly related to the volume of runoff due to the fact, that infiltration rate of the soil goes on decreasing with the duration of rainfall till it attains constant rate. As a result of this even a mild intensity rainfall lasting for longer duration may yield a considerable amount of runoff.

4. Rainfall distribution: Runoff in watershed depends very much on the distribution of rainfall. The rainfall distribution for this purpose can but expressed by a team "distribution coefficient which may be defined as the ratio of maximum rainfall at a point to the mean rainfall of the watershed. For a given total rainfall, if all other conditions are the same, the greater the value of distribution coefficient, greater will be the peak runoff and vice - versa. However, for the same distribution coefficient, the peak runoff would be resulted from the storm, falling on the lower part of the basin i.e. near the outlet.

5. Direction of prevailing wind: The direction of prevailing wind, affected greatly the runoff flow. If the direction of prevailing wind is same as the drainage system then it has great influence on the resulting peak flow and also on the duration of surface flow, to reach at the outlet. A storm moving in the direction of stream slope produces a higher peak in shorter period of time than a storm moving in opposite direction.

6. Other climatic factors: The other climatic factors, such as temperature, wind velocity, relative humidity, annual rainfall etc. affect the water losses from the watershed area to a great extent and thus the runoff is also affecter accordingly. If the losses are more the runoff will be less and vice -versa.

Following are the general items of watershed development which are required to be executed in the catchments area depending upon the prevailing situation.

1. Soil and land management

i) Interceptor drains.

iii) Graded bunding
iv) Bench terracing
v) Interbund vegetative barriers
vi) Grass Waterways.
vii) Improvement of ill drained soils
viii) Nala training / improvement.

2. Water Harvesting Structures:

i) Nala bunding
ii) Farm ponds
iii) Percolation tanks
iv) Minor irrigation tanks
v) Stop dams in nalas
vi) Underground diaphragms.

3. Afforestation cum pasture development for rural energy and forage for animals:

i) On private marginal and culturable waste lands.
ii) On community and Government forest lands.

4. Agricultural development:

i) Selection of crops and their varieties suitable for local soil and climatic situation.
ii) Adoption of appropriate cropping system.
iii) Contour farming.
iv) Strip cropping.
v) Mulching and crop residue management.
vi) Adoption of alternate land use system depending on land capability such as Alley Cropping, Agro - horticulture, silvipastural management, dryland horticulture, tree farming, and pasture management.

<u>Significant Gains From Watershed Development Programme</u>

1. Soil and moisture conservation:

Soil and moisture conservation is the basic need in rained agriculture. Top soil is the most fertile part of the soil profile. This layer is lost due to erosion causing decrease in yield. Agronomic and mechanical measures for soil and moisture conservation are adopted in the watershed such as contour farming, strip cropping, mixed cropping, inter - cropping, contour / graded bunding, vegetative barriers etc.

2. Increase in water storage:

Due to construction of surface water storage structures like minor irrigation tanks, percolation tanks, nala bunds, farm ponds etc. the excess runoff water is collected in these storage structures which in turn is used either for supplement irrigation for field crops, horticultural crops or for drinking water to animals. Thus, additional area can be brought under irrigation.

3. Increase in number of wells:

Due to considerable improvement in ground water recharge, the numbers of dugout wells or tube wells are increased. The farmer can apply protective irrigation to various field crops whenever necessary. Thus the area under well irrigation is increased.

4. Increase in cropping intensity:

Due to increase in water resources and adoption of appropriate crop management practices, and area under double cropping is increased, which results in increasing cropping intensity.

5. Increase in fertilizer use:

Due to increase in water potential and moisture conservation measures, the fertilizer use by the farmers is increased.

6. Improvement in crop production and productivity:

Adoption of vegetative and mechanical conservator measures, results in considerable reduction in soil, water and nutrient losses from the watershed area. Further adoption of improved crop management practices results in appreciable increase in crop productivity and total crop production from these areas.

7. Animal and milk production:

Appropriate management of marginal lands with productive grasses and pastures, the total forage resources are increased which reflects in increasing animal component resulting increase in meat and milk production.

8. Increase in afforestation and alternate land use:

For producing fuel, fodder and timber, alternate land use programme is implemented in watersheds. Dryland horticultural species in addition to fuel and fodder tree species have shown promise in the watersheds.

9. Employment generation and increase in per capita income:

Due to optimization of available resources, there is increase in employment generation to farm families throughout the year. Due to overall increase in production and productivity in the entire watershed, there is considerable increase in per capita income.

Farm ponds : Collecting and storing water on the surface of the soil for subsequent use is known as water harvesting. Farm ponds are one of the techniques of water harvesting in semiarid regions.

Farm ponds of size 100 to 300 m^3 may be dug to store 30 per cent runoff. The problem associated with farm ponds is high seepage loss. This can be reduced by lining walls. Some of the traditional methods for seepage control are the use of bentonite, soil dispersant and soil cement mixture. Bentonite has excellent sealing properties if kept continuously wet, but crack develops when dried. Soil –cement mixture can be used, but surface cracking develops when exposed to sun drying. A soil-cement lining of 100 mm thickness reduces seepage losses up to 100 per cent. The pit lined continuously develops cracks but no cracks develop when applied in blocks. The other alternative sealant for alfisols is mixture of red soil and black soil in the ratio of 1: 2

CROPS PLANNING ACCORDING TO LAND USE CAPABILITY CLASSIFICATION

Definition: Land capability classification is the systematic arrangement of different kinds of land, according to those properties that determine the ability of land to produce crops on the virtually permanent basis.

Factor determining land capability classes

I) Major soil characteristics of land:

1. Soil structure and texture
2. Effective depth of soil
3. Permeability of top and sub soil

II) Associated land factors :

1. Slope of land
2. The extent of erosion
3. Degree of wetness
4. Susceptibility to overflow and flooding

Land capability classification: Any soil and water conservation projects includes two distinct sets of operations *viz*; (1) Mapping of land for classification according to its capacity and (2) Planning and executing measured to check erosion, improve land productivity and reclaim wasteland. The farm plans for effective soil and water conservation are based largely on the capability of the land. Land is classified according to the most suitable sustained use that can be made of it while providing for adequate protection from erosion or other means of deterioration. Thus, an area where the soils are deep, well drained and have a stable surface structure and where the slope is only 1 to 2 per cent may be cropped intensively almost indefinitely with the little danger of erosion or loss in productivity. In contrast, an area on which shallow or poorly drained soils are found or wherein steep slopes are prevalent, has limited capabilities and many limitations as to it use. They all fall into two broad groups,

i) Suitable for cultivation and other land uses

ii) Not suitable for cultivation but suitable for other land uses.

1) Land suitable for cultivation and other uses

Class I:- (Green colour)

Soil found in this land class have few limitation that restrict their use. They can be cropped heavily. The soils are deep, well drained and land is nearly level. They are either naturally fertile or have characteristics which encourage good response of crops to application of fertilizer. The water holding capacity of soils in Class I is high. In arid and semi arid areas soils having all the other favorable characteristics, may be in Class I if they are irrigated by a permanent irrigation system.

These soils need ordinary management practices to maintain productivity. These include, the use of fertilizer and lime and the return of manure and crop residues including green manures. Crop rotations are also followed. The lands are flat or gently sloping (<0.5 per cent slope. No special conservation practices are required except good agricultural practices of tillage, manuring and rotation. The slope of the land is 1 %. Soil in this class are suited to a wide range of plant, may be used for cultivated crops, pasture, forests and wildlife food and covers.

Class II:- Yellow colour)

Soils in this class have some limitations that reduce the choice of plant or require moderate conservation practices. These soils may be used for the same crops as class 1 However, they are capable of sustaining less intensive cropping systems or with the same cropping systems, they require some conservation practices. The limitations of soils in Class II may result from the effects of one or more of the following factors,

i) a gentle slope, ii) a slight susceptibility to erosion, iii) Less than ideal, soil structure and workability, iv) inadequate soil depth, v) slight to moderate alkali or saline conditions and, iv) somewhat restricted drainage.

The management practices that may be required include terracing, strip cropping, contour tillage, rotations involving grasses and legumes and grasses waterways. The lands are gently sloping 0.5-1 per cent, with moderate erodability. The length of slope of land is 1-3 % and depth of soil is from 22.5 to 45 cm.

Class III : (Red colours): -

Soils in Class III have severe limitations that reduce the choice of plants or require special conservation practices or both. Soils in Class III have more restrictions than those in Class II and when used for cultivated crops, the conservation practices are usually more difficult to apply and to maintain. The lands are having steep slopes 1 to 6 per cent with high erodibility

Limitations in the use of soils in Class III results from factors such as i) moderately steep slopes, ii) high erosion hazards, iii) very slow water permeability, iv) shallow depth and restricted root zone, v) low water holding capacity, vi) low fertility, vii) moderate alkali or Salinity and

Mechanical soil conservation structures such as contour terraces, trenches and estabilized water channels for disposal of excess rain water in addition to contour cultivation, contour strip cropping and dry farming practices are required for management of these lands. The length of slope of land is 3-5 % . These soils may be used for Agri.-Horticulture and alley cropping

Class IV:- (Blue colour) :-

Soil in this class can be used cultivation but there are very severe limitations on the choice of crops. Also very careful management may be required. The alternative uses of these soils are more limited than for class III. Close growing crops must be used extensively and row crops cannot be grown safely in most cases. The choice of crops may be limited by excess moisture as well as by erosion hazards. These are badly eroded with more than 6 per cent slope. Soil depth is less than 22.5 cm. these lands are used for grazing and afforestation with special conservation measures such as contour trenching, gully plugging, etc.

The most limiting factors on these soils may be one or more of the following I) steep slopes, ii) severe erosion susceptibility, iii) severe past erosion iv) shallow soils, v) low water holding capacity, vi) poor drainage and vii) Severe alkali or salinity. Soil conservation practices must be applied more frequently than on soils in class III. The length of slope of land is 5-10 % .

II) Land not suitable for cultivation but suitable for other land uses: - Soils in class V to VIII are generally not suited to cultivation.

Class V:- (Dark green or uncoloured)

Soils in Class V have little or no erosion hazard, but have other limitations, the removal of which is not practicable. Examples of such limitations follow I) subject to frequent stream overflow, ii) growing season too short for crop plants, iii) stony or rocky soils and iv) Drainage is not feasible in ponded areas, have often times postures can improved on this class of land. Soils in class V are not suitable for raising cultivable crops, but are suitable for perennial vegetation (grazing and forestry, with few or no limitations). These soils are badly eroded having > 6 per cent slope and 7.5 cm soil depth.

Physical conditions of these soils are such that it is practicable to apply pasture improvements, if needed, such as seeding, liming, fertilizing and water control with contour furrows, drainage ditches, diversion of water spreaders. The length of slope of land is 10-15 % . These soils are not suitable for raising cultivated crops, but are suitable for peramanet vegetation (Silvipasture)

Class VI):- (Orange colours) :

Soils in this class have severe limitations that restrict their use largely to pastures range, woodland or wild life.

Soils have continuing limitations which cannot be corrected, such as I) a steep slope, ii) very severe erosion, iii) very severe effect of past erosion, iv) stoniness, v) shallow rooting zone vi) excessive wetness or over flow, vii) low moisture capacity, viii) salinity or sodium and ix) severe climate. Soils in this class are subject to moderate limitations under grazing or forestry use. The land slope in this class varies from 15-25 %.

Class VII):- (Brown colour):-

Soil in Class VII have very severe limitations that make them unsuitable for cultivation and that restrict their use largely to grazing or forestation or wild life food and cover, soils in Class VII have very severe limitations which restrict their use to grazing, woodland or wild life. The physical condition of soil is such that it is not practicable to adopt pasture improvement and water control practice. The land slope in this class varies from 25-33 %.

Class VIII:- (Purple colour):-

In this land class soils that should not be used for any kind of commercial plant production. Their use is restricted to recreation, wild life, water supply or aesthetic purposes. Limitations which cannot be corrected may result from the effects of one or more of the following factors I) erosion or erosion hazard, ii) Severe climate, iii) wet soil, iv) stones , v) low moisture capacity and vi) salinity of sodium. The land slope in this class is > 33 %.

Bad lands, rock out crops, sandy beaches, marshes, deserts, river wash, mine tailings and other nearly barren lands are included in Class VIII.

Land capability sub-classes:- In each of the land capability classes are sub classes which have the same kind of dominant limitations for agricultural use. The four kinds of limitations recognized in these sub-classes are: risks of erosion (e) wetness, drainage or overflow (w), root zone limitations (s) and climatic limitations (e). Thus a soil may be found in class III (e) indicating that it is class II because of risks of erosion where two kinds of limitations can be modified or corrected and are essentially equal, the sub-classes have the following priority e, w, s, c, : where soils have two kinds of limitations, the dominant one is shown first.

This land classification illustrates the use which can be made of soil surveys in a practical way. The many soils/delineated on a map by the soil surveyor are viewed in the light of their safest and best long time use. The eight land capability classes have become the starting point in the development of farm plans so useful to farmers.

Land use planning: - In the case of land use planning the objective is the efficient intensive use of land resources. In land use planning, the first step of collecting the information about the land is to carry out surveys and determine the soil properties. Next the data are sorted and analyzed into the soil codes and capability classes when the land has been investigated and classified, the alternatives can be weighted up and the decisions made. Then comes the fourth step of carrying out plan and finally assessing the results to see if the objective has in fact been achieved. The last stage of evaluation is as vital as any other, for these may have been some unknown factor which has prevented the plan working.

The land capability is a vital valuable tool in land use planning for it ensures the logical and systematic collection of data about the soil, and presents the results in a form most useful to the planner. There are also the economic, political and social aspects which must also be investigated.

The existing land use of different regions has been evolved as the result of the action and interaction of various factors such as the physical characteristics of land. The institutional frame works, the structure of other resources (capital, labour, etc) available and location of the region' in relation to other aspects of economic development *viz*; these relating to transport as well as to industry and trade. A close study of the present land use patterns and trends during recent years will help to suggest the scope for planned shifts in the pattern.

Table : Suitability for cropping, special precaution and alternate land use options for different land capability classes

	Land capability class	Suitable for intensive cultivation or not	Special precautions	Preferable alternated land use other options
I.	Very good cultivable land	Intensive cultivation for all crops depending on soil and climate	-	-
II.	Good cultivable land	Cultivation with precaution	Minor soil erosion	Agri-horticulture
III.	Moderately good cultivable land	Cultivation with precaution against permanent land damage	Special attention to erosion control	Agri-horticulture, selected legumes and grasses.
IV.	Fairly good land suitable for occasional cultivable	Occasional cultivation in rotation with pasture or orchards protected by permanent cover crops.	Intensive erosion control	Silvi-pasture, silvi-pasture, silviculture, Horti-pasture grasses.
V.	Nearly leveled land not suitable for cultivation because of stoniness, wetness etc.	Not suitable	When developed as rangeland regulated grazing.	Agro-horticulture, Silvi-pasture
VI.	Steep slopes, highly erosion prone with erosion prone with shallow soil.	Not suitable	Careful management if developed a forest or grazing land.	Agro-horticulture, silvipasture system.
VII.	Steep slope with severe soil erosion resulting in eroded stony and rough soil surfaces with shallow soil depth.	Not suitable	Contour trenching, gully control works and controlled grazing	Silvipasture, pasture
VIII.	Stony Hill Rocks	Not suitable for any kind of commercial	Limitations can not be corrected -	Recreation or wild life, water supply

		plant production	erosion, severe climate, wet soil	or aesthetic purpose.

IMPORTANT QUESTIONS

1. Define rainfed agriculture. Enlist its characteristics and differentiate between dryland farming and rainfed farming
2. Write the historical events of rainfed agriculture and watershed management
3. Describe in short the problems or constrains of rainfed agriculture
4. Enlist the agro-climatic zones of Maharashtra state with their head quarter and describe the Western Maharashtra scarcity zone (Sholapur) in details
5. Describe the varies types of soils of rainfed region
6. Write in details regarding climatic conditions prevailing in rainfed region
7. Enlist the measures of soil and water conservation and describe in short about agronomical/ cultural measures for soil and water conservation
8. What do you mean by drought? Give its classification and describe regarding agricultural drought
9. Write in short the crop adaptation and mitigation to water stress condition
10. Define drought and write the effect of moisture stress on the plant
11. What is water harvesting? write the methods and techniques of water harvesting
12. Describe the various steps involving in water harvesting
13. Write in short the different crop production practices to sustain the crop yield in rainfed area
14. Give the contingent crop planning under aberrant weather conditions
15. Write the concept of watershed management and describe the component of watershed management
16. Give the objectives and principle of watershed management
17. Define watershed and write in short the factors affecting watershed management
18. Differentiate between dry farming, dryland farming and rainfed farming

Short notes:

1	Strip cropping	2	Mulching
3	Antitranspirants	4	Minimum tillage
5	Double cropping	6	Enlist the agro climatic zones of India
7	Cropping pattern	8	Watershed delineation
9	Critical growth stages of crops	10	Reason of low productivity in rainfed area
11	Bunding for soil & water conservation	12	Microwatershed

OBJECTIVES

1.	The head quarter of the ICRISAT is located at .... i) **Hyderabad** ii) Solapur iii) Bijapur iv) Rohatak
2.	The head quarter of the CRIDA is located i) Rohatak ii) Lucknow iii) **Hyderabad** iv) Solapur
3.	The cultivations of the crop in areas where rainfall is less than ....is called dry farming i) **<750 mm** ii) > 750 m iii) 750-1150 m iv) None of the above
4.	Dry land farming cane be defined as the cultivation of the crops where rainfall is............ i) Less than 750 mm ii) **More than 750 mm** iii) 750 mm-1150 mm iv) None of the above
5.	Which is the major constraints in case of rainfed farming i) **Wind and water erosion** ii) Water erosion iii) Wind erosion iv) None of the above
6.	Which is one of following soil has a major problem of drainage i) Literate soil iii) **Vertisole** iii) Alluvial soil iv) None of the above
7.	The formula for MDI is i) $\frac{P-PE}{PET}$ ii) **$\frac{P-PET}{PET} \times 100$** iii) $\frac{P \times 100}{E}$ iv) None of the above
8.	The south west man soon contribute about .... % rainfall i) 85 % ii) 95 % iii) 75 % iv) **80 %**
9.	Which is one of the following Antitranspirants is stomatal closing type i) Kaoline ii) Cycocel iii) Celite iv) **PMA**
10.	Which is the key elements in dryland crop production i) **Nitrogen** ii) Phosphorus iii) Potassium iv) Calcium
11.	The growing few or more crops simultaneously on a peace of land is called as .... i) Double cropping ii) Sequence cropping iii) **Intercropping** iv) Mixed cropping
12.	The central arid zone research institute was established on........... i) 1960 ii) 1965 iii) **1959** iv) 1970
13.	The All India co-ordinated research project on dry land agriculture (AICRPDLA) was established i) 1975 ii) 1965 iii) **1972** iv) 1971
14.	What is mean by drought year **i) Rainfall is less than 75 % less than normal value** ii) Rainfall is less than 50 % less than normal value iii) Rainfall is less than 80 % less than normal value iv) None of the above
15.	The dry farming research on small plots at Manjari near Pune was established on .... i) **1923** ii) 1925 iii) 1927 iv) 1932
16.	Which type of the cropping is adopted in dry land farming i) Double cropping ii) Sequent cropping iii) **Monocropping and intercropping** iv) Mixed cropping
17.	The vertical mulching is useful in .... type of the soil i) **Black cotton soil** ii) Alluvial soil iii) Light soil iv) Red soils
18.	Which is one of the following one Antitranspirants is used as a growth retardants i) **CCC** ii) PMA iii) Atrazine iv) None of the above
19.	Implement developed by ICRISAT Hyderabad for dryland agriculture is........ i) Wheel chair ii) **Tropicultor** iii) Multiple device iv) Mould board plough

20.	Which of the following is in situ method of soil moisture determination i) **Tensiometer** ii) Electrical resistance method iii) Neutron probe method iv) Gravimetric method
21.	For which of the following purpose lysimeter is used? i) Determination of crop growth ii) **Determination of water requirement of crop** iii) Determination of nitrogen requirement of crop iv) Determination of crop weed competition
22.	Transpiration is the loss of moisture from.......... i) Soil ii) Water iii) **Vegetation** iv) Soil and vegetation
23.	Crop recommended for in-situ green manuring is .... i) **Sannhemp** ii) Subabul iii) Ipomea iv) Glyricida
24.	Moisture deficit Index (MDI)= .... i) **P-PET/PET** ii) P-PET/PET iii) P-PET/T iv) DET-P/PET
25.	
26.	Development of plasticity is due to...... mechanism i) Drought avoidance ii) Drought escape iii) **Drought tolerance** iv) Drought resistance
27.	Drought resistant varieties open their stomata more rapidly during.... i) Evening ii) **Early morning** iii) Late afternoon iv) Night
28.	The most drought resistant crops called as .... i) C_3 ii) C_4 iii) **CAM** iv) All above
29.	PMA is classified as ..... i) Film farming ii) **Stomata closing** iii) Reflectant type iv) Growth retardant
30.	In semi arid region, the practical method of water harvesting is .... i) Dug wells ii) Tanks iii) Runoff farming iv) **Farm ponds**
31.	The area under dryland farming is .... i) **34.5 m.ha** ii) 39.0 m.ha. iii) 40.0 m.ha. iv) 41.5 m.ha
32.	The sustainable cropping system under rainfed farming is................ i) Mix cropping ii) **Inter cropping** iii) Sequence cropping iv) Mono cropping
33.	Which of the following is categorized as agronomic measure for soil and moisture conservation i) Graded bunding ii) Bench terracing iii) **Contour farming** iv) None of the these
34.	The most practical approach to conserve the soil moisture in dryland agriculture......... i) **Dust much** ii) Polythene mulch iii) Stubble mulch iv) Trash mulch
35.	Widely adopted intercropping system under rainfed agriculture is.... i) Bajra+Pigenon pea ii) **Sorghum + pigeon pea** iii) Cotton + Pigeon pea iv) Cotton + Soybean
36.	Which method is most suitable to increase th fertilizer use efficiency (FU) i) Deep placement ii) Broad casting iii) **Drilling** iv) Band placement
37.	Which technique is suitable when dry spell occures during seedling stage i) **Thinning** ii) Mulching iii) Spray of Antitranspirants iv) Spraying of K

38.	Watershed development programme includes the component of ..... i) Command area ii) Catchments area iii) water harvesting iv) **All of these**
39.	A day a considered as the rainy days when rainfall exceeds ..... i) 2.0 mm ii) **2.5 mm** iii) 3.5 mm iv) 5.0 mm
40.	Select the drought tolerant crop from the following i) Sunflower ii) Groundnut iii) Soybean iv) **Arhar**
41.	Which crop is used as indicator plant for moisture stress? i) Arhar ii) Greengram iii) Castor iv) **Sunflower**
42.	Stomata is regulated by nutrient....... i) N ii) P iii) **K** iv) Ca
43.	Cropping scheme is the ...... i) List of crops ii) **Crops plan** iii) Plan of enterprises iv) Plan of operations
44.	Any subsidiary crop grown in association with a main crop is called as .... i) Supplementary crop ii) Intercrop iii) Mixed crop iv) **Companion crop**
45.	.... is main object of mixed farming........ i) Sustainability ii) Commercial iii) Diversification iv) **Subsistence**
46.	Cropping intensity index indicated the ..... of times a field is grown with crops in a year i) Volume ii) **Number** iii) weight iv) Mass
47.	Gypsum used for agriculture purpose should be .... % pure. i) 1 ii) **65** iii) 100 iv) 10
48.	Gypsum is used for reclamation of .... soils i) Saline ii) Acidic iii) **Alkali** iv) Lateratic
49.	Salinity stress in plant is of often....... i) Climatological drought ii) Biological drought iii) **Physiological drought** iv) Nutrient drought
50.	The hedge row intercropping is known as.......... i) **Alley cropping** ii) Mulch cropping iii) Sequence cropping iv) None of the above
51.	.... is the most limiting factor in dry land Agriculture i) Evaporation ii) **Moisture** iii) Soil mulch iv) Straw mulch
52.	Terracing method of soil and water conservation is mostly adopted in areas having slope is more than. i) > 20 ii) **> 10** iii) 20-25 iv) >30
53.	The effectiveness of mulch is more visible .... rainfall area i) Adequate rainfall area ii) **Low rainfall area** iii) Very less rainfall area iv) None of the above
54.	.... grass is the most suitable for planting on contour to control erosion i) **Khus grass** ii) Para grass iii) Stylohemata iv) None of the above
55.	Which is one of the following one species of the earthworm most widely used in word in vermitechnology for vermicomposting i) Eudrilus eugeniae ii) **Eisenia foetida (sav)** iii) Eudrillaidae iv) None of the above
56.	Which of the following is not a smother crop i) Sannhemp ii) Soybean iii) Lucern iv) **Onion**

57	The process that occurs in legume when in symbiosis with *rhizobia* bacteria			
	i	**Nitrogen fixation**	ii	Denitrification
	iii	Volatilization	iv	Immobilization
58	The Central Soil and Water Conservation Research and Training Institute is located at			
	i	Jhansi	ii	Hyderabad
	iii	Bangalore	iv	**Dehradun**
59	The Indian Grassland and Fodder Research Institute is located at			
	i	**Jhansi**	ii	Kanpur
	iii	Bangalore	iv	Dehradun
60	The Indian Institute of Pulses research is located at			
	i	Jhansi	ii	**Kanpur**
61	iii	Bangalore	iv	Dehradun
	The National Institute of Research on Jute and Allied Fibre Technology is located at			
	i	Jhansi	ii	Kanpur
	iii	**Kolkata**	iv	Dehradun
62	The National Institute of Abiotic Stress Management is located at			
	i	**Pune**	ii	Kanpur
	iii	Jhansi	iv	Dehradun
63	The Directorate of Rapeseed & Mustard Research is located at			
	i	Pune	ii	Kanpur
	iii	Jhansi	iv	**Bharatpur**
64	The Directorate of Rice Research is located at			
	i	Pune	ii	Kanpur
	iii	**Hyderabad**	iv	Bharatpur
65	The Directorate of Oilseed Research located at			
	i	Pune	ii	**Hyderabad**
	iii	Kanpur	iv	Bharatpur
66	The Directorate of Sorghum Research located at			
	i	**Hyderabad**	ii	Pune
	iii	Kanpur	iv	Bharatpur
67	The Central Tobacco Research Institute located at			
	i	**Rajahmundry**	ii	Bangalore
	iii	Kanpur	iv	Bharatpur
68	The Directorate of Soybean Research is located at			
	i	Rajahmundry	ii	Palampur
	iii	**Indore**	iv	Bharatpur
69	Which type of plants is more drought tolerant?			
	i	C_4	ii	C_3
	iii	**CAM**	iv	Both a and b
70	Normal onset of Southwest monsoon at Kerala in India is during			
	i	**End of May**	ii	Mid June
	iii	End of June	iv	None of these
71	What amount of water is lost through evaporation under dryland situation?			
	i	20-30%	ii	0-60%
	iii	**60-75%**	iv	75-90%
72	Mulches are advantageous under dryland condition, identify the correct reason			
	i	Reduce runoff	ii	Improve infiltration
	iii	Reduce beating action of rains	iv	**All of these**
73	Watershed is also called as			

	i	Catchment area	ii	Drainage basin
	iii	**Both a and b**	iv	None of these
74	Which is the important approach in micro watershed?			
	i	Soil conservation	ii	Soil improvement
	iii	Storage of run-off-water	iv	**All of these**
75	Which of the storage structure will recharge ground water and ultimately used for protective irrigation?			
	i	Farm ponds	ii	Percolation ponds
	iii	Silt distension tanks	iv	**Both b and c**
76	Inter-row and intra-raw water harvesting is beneficial, select the appropriate option			
	i	Improving crop stand for small crops	ii	Safe disposal of excess water
	iii	Reducing runoff	iv	**All of these**
77	Which of the following is the method of micro catchments?			
	i	Compartmental bunding	ii	Crescent basin
	iii	Circular basin	iv	**All of these**
78	Percentage of runoff under *Vertisols* and *Alfisols* is ______ and ______			
	i	**60, 40**	ii	30, 20
	iii	20, 70	iv	90, 10
79	Which is the important runoff water harvesting method under dryland areas?			
	i	Water harvesting structures (farm ponds, check dams)	ii	Traditional tanks
	iii	Percolation tanks	iv	**All of these**
80	*Nalla* bunding is beneficial because			
	i	Impounds water in Nallas/gullies	ii	Check soil erosion and runoff
	iii	Reduce free flow of water	iv	**All of these**
81	Best site for farm pond is			
	i	Few fields there must be irrigated by free flow	ii	Maximum of runoff flow area
	iii	Largest storage volume with least earth work	iv	**All of these**
82	Size of farm pond per hectare of area is ______ m^2			
	i	200	ii	**250-300**
	iii	500	iv	None of these
83	Commonly used lining materials in farm pond is made of following			
	i	Clay and Bituminous material	ii	Soil/cement mixture and brick lining
	iii	Cement concrete and chemical additives	iv	**All of these**
84	Major storage loss of farm pond is			
	i	Seepage	ii	Percolation
	iii	Evaporation	iv	**All of these**
85	Evaporation reducing material used in farm pond is			
	i	Wax	ii	Oil emulsions
	iii	Non ionic chemicals	iv	**All of these**
86	Areas with 20-30 weeks of cropping season, which type of cropping is suitable?			
	i	Single cropping	ii	**Intercropping**
	iii	Double cropping	iv	All of these
87	Successful pre-monsoon sowing depends on			
	i	Prediction of monsoon	ii	Seed hardening
	iii	Depth of sowing	iv	**All of these**
88	Advantage of seed pelleting is			
	i	Easy to incorporate with nutrients	ii	Seeds protected against pests
	iii	Uniform shape of seeds	iv	**All of these**

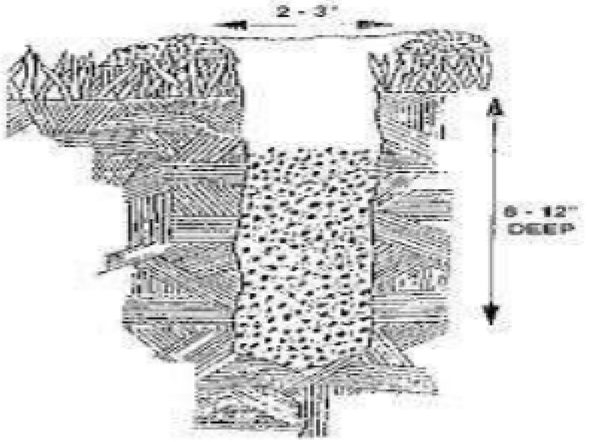
89	Crops chosen under delayed onset of monsoon is			
	i	Pulses	ii	Cereals
	iii	Oilseeds	iv	**Both a and c**
90	Which among the crop is well adapted to transplanting under late onset of monsoon?			
	i	**Finger millet**	ii	Pearl millet
	iii	Foxtail millet	iv	None of these
91	Main component of watershed is			
	i	Soil and water conservation	ii	Water harvesting and crop management
	iii	Alternate land use system	iv	**All of these**
92	Major soil type in India is			
	i	**Red soil**	ii	Black soil
	iii	Alluvial	iv	Coastal soil
93	Soil erosion is a process of			
	i	Detachment of soil particles	ii	Transportation of soil particles
	iii	**Both a and b**	iv	Transport of water
94	Most spectacular symptom of soil erosion is			
	i	Sheet erosion	ii	Rill erosion
	iii	**Gully erosion**	iv	Landslides
95	Rate of erosion depends on			
	i	Intensity of rainfall	ii	Slope of soil
	iii	Type of soil and vegetation	iv	**All of these**
96	According to the land use capability classification, classes suitable for agriculture is			
	i	**I-IV**	ii	I-II
	iii	I-VIII	iv	I-VI
97	Example of Class I under land capability classification is			
	i	**Alluvial soils and Gangetic plains**	ii	Deep red or black soils
	iii	Shallow saline soils	iv	All of these
98	Suitable cropping and conservation measures under Class II of land use capability classification is			
	i	Strip cropping	ii	Contour tillage
	iii	Legume-grass rotation	iv	**All of these**
99	Vegetation suitable for Class VI of land capability classification is			
	i	Pasture	ii	Wood land
	iii	**Both a and b**	iv	None of there
100	Which of the following is a stage of wind erosion?			
	i	Saltation	ii	Surface creep
	iii	Suspension	iv	**All of these**
101	Watershed aims to			
	i	Soil water conservation	ii	Increasing productivity
	iii	Economic profitability of farm	iv	**All of these**
102	Soil erosion is high in semi arid region because of			
	i	High intensity of rainfall	ii	Low protective vegetation
	iii	Vulnerability of soil to erosion	iv	**All of these**
103	Contour bunding is suitable to______ soil			
	i	**Medium black**	ii	Red
	iii	Deep black	iv	Alluvial
103	Compartmental bunding is suitable in			
	i	Rainfed red soils	ii	<1 % sloppy areas
	iii	Short duration crop	iv	**All of these**
104	Yield increase of *in-situ* moisture conservation measures over control in rainfed areas ranged between			
	i	<10%	ii	10-20%
	iii	**15-50%**	iv	80%

105	Broad bed and furrow is evolved by			
	i	**ICRISAT**	**ii**	CRIDA
	iii	IARI	**iv**	IRRI
106	Area subjected to erosion in India is			
	i	100 m ha	ii	150 m ha
	iii	**162 m ha**	iv	200 m ha
107	Wind erosion is a major problem in			
	i	**Southern India**	ii	Western India
	iii	North Eastern India	iv	Northern India
108	Estimated loss of top soil in India is			
	i	1000 mt	ii	2500 mt
	iii	**5000 mt**	iv	1000 mt
109	The International Centre for Agriculture Research in Dry Areas (ICARDA) was established in			
	i	1987	ii	**1977**
	iii	1967	iv	None of these
110	The ICRISAT was established in			
	i	1987	ii	**1972**
	iii	1967	iv	None of these
111	The CRIDA was established in			
	i	1987	ii	**1982**
	iii	1967	iv	None of these
112	The dryland areas can be designated where			
	i	Annual rainfall is equal to potential evapotranspiration	ii	**Potential evapotranspiration is more than annual rainfall**
	iii	Potential evapotranspiration is equal to annual rainfall	iv	None to these
113	Under stress condition, which amino acid accumulated in crop plants			
	i	Methionine	ii	Tryptophan
	iii	**Proline**	iv	Phenyl alanine
114	What sort of aberration in rainfall affects crop growth most :			
	i	Lesser rainfall	ii	Higher rainfall
	iii	**Uncertain distribution**	iv	No rain in reproductive stage
115	Which one can be called as Dryland?			
	i	**When rainfall received is less than 1000mm**	ii	When rainfall received is less than 500 mm
116	iii	When rainfall received is less than 750 mm	iv	Hilly terrain with low rainfall less than 500 mm
117	In undulating terrain one should go for__________			
	i	Normal crop raising	ii	**Strip cropping**
	iii	Pastoral cropping	iv	Mixed pastoral and tree cropping
118	Which one can be called as Dryfarming?			
	i	When rainfall received is less than 1000mm	ii	When rainfall received is less than 500 mm
	iii	**When rainfall received is less than 750 mm**	iv	Hilly terrain with low rainfall less than 500 mm
119	Which one can be called as Rainfed farming area?			
	i	When rainfall received is more than 1150 mm	ii	When rainfall received is less than 500 mm
	iii	**When rainfall received is more than 800 mm**	iv	Hilly terrain with low rainfall less than 500 mm
120	Dry farming areas are characterized by a growing season of			
	i	**<75 days**	ii	75-120 days

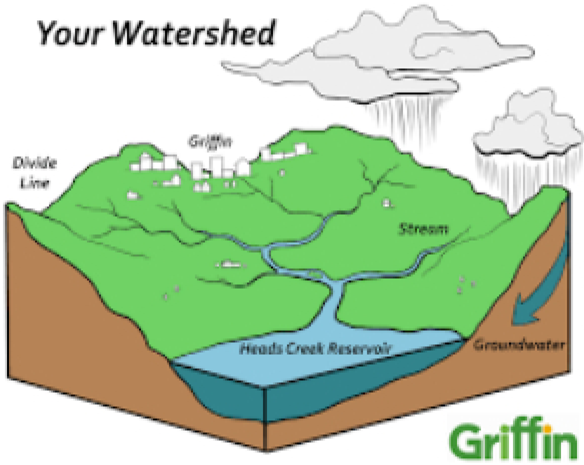
	iii	>120 days	iv	All
121	Rainfed farming areas are characterized by a growing season of			
	i	<75days	ii	**75-120 days**
	iii	>120 days	iv	All
122	In dry farming areas emphasis is on			
	i	**Moisture conservation practices**	ii	Drainage
	iii	Disposal of excess water	iv	All
123	The first dry farming research station started in the year 1923 at			
	i	Bijapur	ii	Sholapur
	iii	Rohtak	iv	**Manjri**
124	The dry farming research station started in the year 1935 at			
	i	Bijapur	ii	Sholapur
	iii	Manjri	iv	**Rohtak**
125	The dry farming research station was started in the year 1934			
	i	Hagari	ii	Raichur
	iii	Manjri	iv	**Both a & b**
126	The first scientific approach to tackle the problem of dry farming areas was initiated by			
	i	Kanitkar	ii	Swaminathan
	iii	**Tamhane**	iv	None
127	Which of the following is not a kind of drought			
	i	Invisible	ii	**Climatic**
	iii	Seasonal	iv	Permanent
128	Desert climate is the characteristic of ………. Drought			
	i	Invisible	ii	Climatic
	iii	Seasonal	iv	**Permanent**
129	Vertical mulching has been adopted in			
	i	**Heavy soils**	ii	Light soils
	iii	Loamy soils	iv	All of these
130	The broad beds and furrow method is suitable for			
	i	**Black soils**	ii	Sandy soils
	iii	Loamy soils	iv	All
131	Evaporation from soils surface can be restricted by			
	i	Reducing external evaporativity	ii	Reducing energy supply to evaporating surface
	iii	Using growth retardants	iv	**All of the above**
132	Transpiration can be restricted			
	i	Use of antitranspirants	ii	Increasing leaf reflectance
	iii	Affects the closure and opening of stomata	iv	**All of the above**
133	Atrazine used as an antitranspirant			
	i	**Reduces the growth of the crop**	ii	Does not reflect light from plant leaf surface
	iii	Affects the closure and opening of stomata	iv	Forms thin layer on leaf surface
134	Phenylmercuric acetate (PMA) is a chemical used in agriculture crops in order to			
	i	Increase CO_2 uptake	ii	Reduce respiration
	iii	**Reduce transpiration**	iv	Increase transpiration
135	Dust mulch is very effective in			
	i	Coarse textured soil	ii	**Heavy textured soil**
	iii	Sandy soil	iv	None of these
136	Normally drought is assessed using			
	i	**Aridity**	ii	Dryness

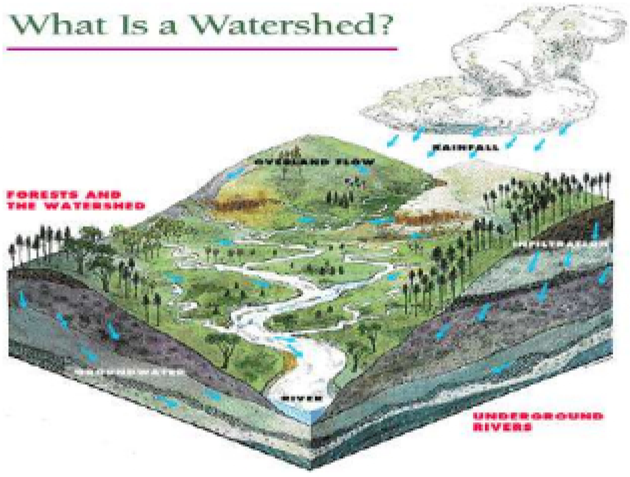
	iii	Aridity anomaly index	iv	Deficient rainfall
137	Materials which reduces water loss from leaf surface by reducing the size or number of stomatal openings are called			
	i	Growth retardants	ii	Growth promoters
	iii	Antitranspirants	iv	**All**
138	………. is a stomata closure type of antitranspirants			
	i	**PMA**	ii	Kaolin
	iii	Mobileaf	iv	All
139	……… is a film forming type of antitranspirants			
	i	PMP	ii	Kaolin
	iii	**Mobileaf**	iv	All
140	……… is a leaf reflectance type of antitranspirants			
	i	PMA	ii	**Kaolin**
	iii	Mobileaf	iv	All
141	Coating of the leaf surface with white material increase			
	i	**Albedo**	ii	Stomatal closure
	iii	Leaf reflectance	iv	All
142	CCC is a ………. Type of antitranspirants			
	i	Film forming	ii	Stomatal closure
	iii	**Growth retardant**	iv	All
143	Soil mulch reduces			
	i	Deep cracking	ii	Reduces evaporation
	iii	Improves water storage	iv	**All**
144	Hedgerow intercropping is the			
	i	**Cultivation of food crops in alleys formed by hedge row of tress / shrubs in arable lands**	ii	Cultivation of food crops in alleys formed by hedge row of trees / shrubs in waste lands
	iii	Cultivation of food crops in alleys formed by hedge row of trees / shrubs in forest lands	iv	All of the above
145	Which is a alley system			
	i	Forage-alley cropping	ii	Forage-cum-mulch system
	iii	Forage-cum-pole system	d.	**All**
146	Which one of the following chemical is used as antitranspirant in dryland crops			
	i	2,4-D	ii	MCPA
	iii	**Cycocel**	iv	Paraquat

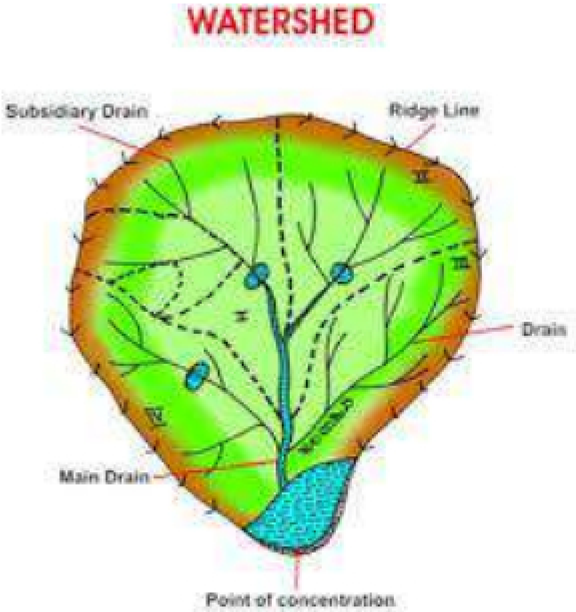
Photographs

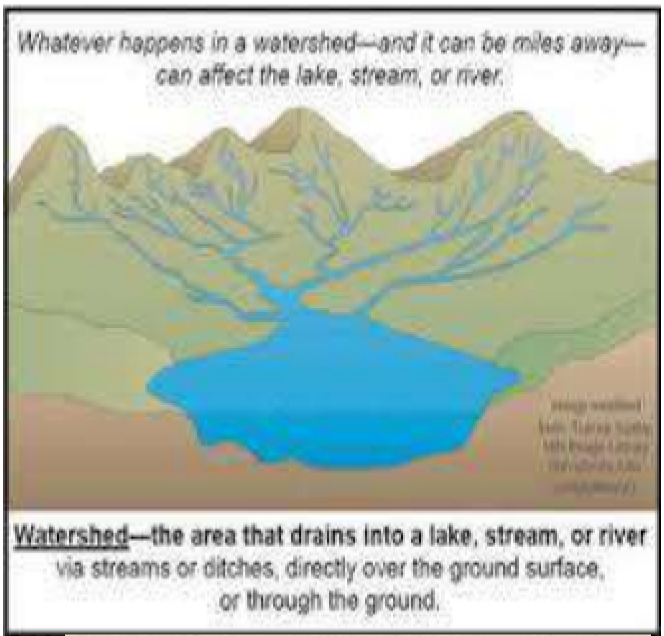


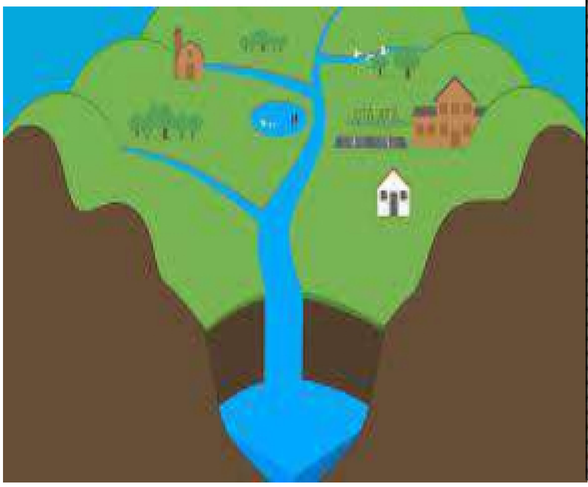
MULCHING PACTICES

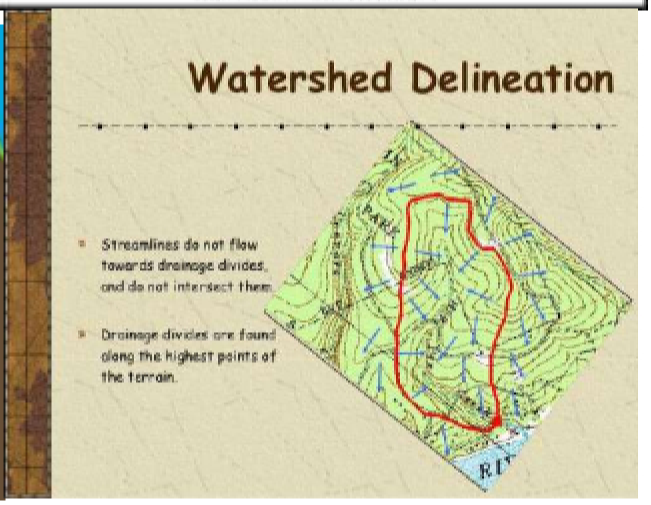












WATERSHED MANAGEMENT

MECHANICAL MEASURES FOR SOIL & WATER CONSERVATION

WATER HARVETING SRUCTURES

AGRONOMICAL MEASURES FOR SOIL & WATER CONSERVATION