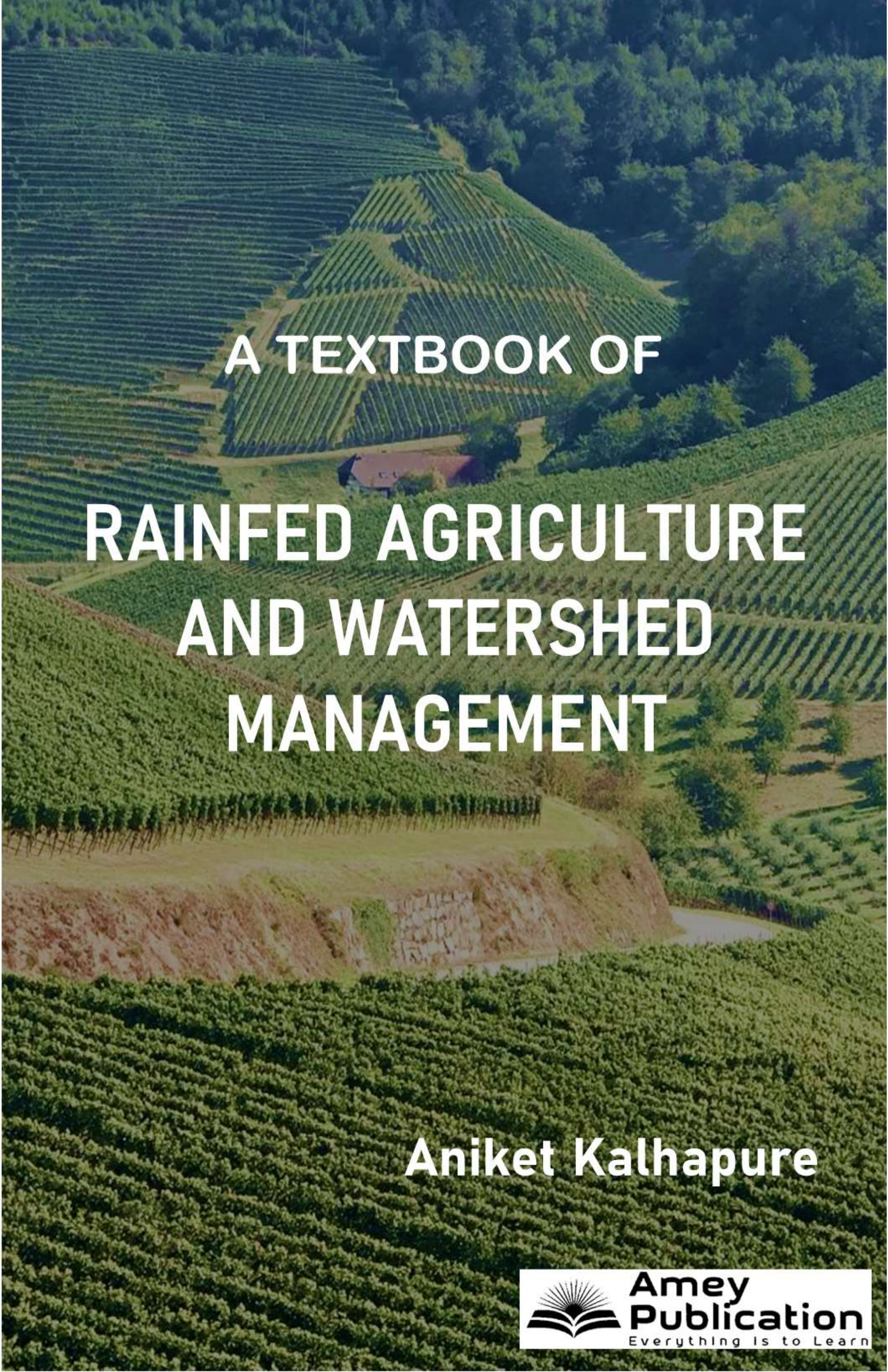

A TEXTBOOK OF

RAINFED AGRICULTURE AND WATERSHED MANAGEMENT

Aniket Kalhapure

Amey Publication
Everything Is to Learn

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Rainfed Agriculture and Watershed Management

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Publisher
Smt. Yogita Rokade
Amey Publication,
Old Kangar Road
Rahuri- 413 705
Maharashtra
Mobile: 8423143507
❖
Printing
Satyabhama Printers
Rahuri- 413 705
❖
ISBN- 978-81-958949-1-8

A Textbook of Rainfed Agriculture and Watershed Management

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Publication Year: 2022
❖
Price: ₹ 200/-

PREFACE

Education system of India is passing through the state of transition, which making learning system more comprehensive and practically efficient. Agriculture education policy of ICAR is also focusing upon the dissemination of more reliable and relevant knowledge among the agricultural students. It is really important for bringing more competence in Indian agriculture for maintaining sustainability of the production systems. Periodical improvements in the syllabus of UG and PG programmes is one of the important steps taken for making the pace of the standard of agricultural education with current time. As per the recommendations of fifth Dean's Committee of ICAR; all State Agricultural Universities also have revised UG and PG syllabus for different courses. The honest intension of publication of this series of text books is to provide more updated and relevant study material for the UG and PG students to expose the in-depth knowledge of the syllabus in course curriculum. The present book entitled "A Textbook of Rainfed Agriculture and Watershed Management" is comprehensively fulfilling the requirement of UG and PG students for the course examinations. It is also very important for the preparation of ICAR JRF, SRF, NET, ASRB along with other competitive examinations conducted by State and Central Governments for different recruitments in various departments. Several years' experience of teaching to the agricultural UG, PG and PhD students in this subject of the author was extremely important to brought the higher-level practical utility in this book. Therefore, the book with be also helpful for the faculties and researchers of the subject of Rainfed Agriculture and Watershed Management.

I am very happy to handing over this book to the readers and wishing for the great success of all the beneficiaries. I also represent my grateful thanks to the Publisher of this book Smt. Yogita Rokade for taking the necessary streps for timely publishing the book.

Date: 07.06.2022
Place: Banda

Aniket Hanumant Kalhapure
Ph.D. (Agronomy)
Assistant Professor of Agronomy
Banda University of Agriculture &
Technology, Banda. U.P- 210 001

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1.
INTRODUCTION, TYPES AND HISTORY OF RAINFED AGRICULTURE & WATERSHED IN INDIA

Rainfed Agriculture

Growing of crops entirely under rainfed conditions i.e. with using rain water is known as rainfed agriculture. 'Rainfed Agriculture' and 'Dryland Agriculture' are the concepts often used synonymously. However, more appropriate concepts of rainfed and dryland agriculture are having some critical differences according to the climatic factors and methodology of farming which will be elaborated in next chapters of this book.

Types Rainfed Agriculture

Depending on the amount of rainfall received and some specific agroclimatic conditions, rainfed agriculture can be grouped into three categories:

a) **Dry farming:** is cultivation of crops in regions with annual rainfall less than 750mm. Crop failure is most common due to prolonged dry spells during the crop period. These are arid regions with a growing season (period of adequate soil moisture) less than 75 days. Moisture conservation practices are necessary for crop production.

b) **Dryland farming:** is cultivation of crops in regions with annual rainfall more than 750 mm. In spite of prolonged dry spells crop failure is relatively less frequent. These are semi arid tracts with a growing period between 75 and 120 days. Moisture conservation practices are necessary for crop production. However, adequate drainage is required especially for vertisols or black soils.

c) **Rainfed farming:** is crop production in regions with annual rainfall more than 1150 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.

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-

Constituent	Dryland farming	Rainfed farming
Rainfall (mm)	<800	>800
Moisture availability to the crop	Shortage	Enough
Growing season (days)	<200	>200
Growing regions	Arid and semiarid as well as uplands of sub-humid and humid regions	Humid and sub humid regions
Cropping system	Single crop or intercropping	Intercropping or double cropping
Constraints	Wind and water erosion	Water erosion

Importance of Rainfed Agriculture in India

i. About 70% of rural population lives in dry farming areas and their livelihood depend on success or failure of the crops

ii. Rainfed Agriculture plays a distinct role in Indian Agriculture occupying 49% of net cultivated area and supports 40% of human population and 60 % livestock population.

iii. The contribution (production) of rainfed agriculture in India is about 42 per cent of the total food grain, 75 per cent of oilseeds, 90 per cent of pulses and about 70 per cent of cotton.

iv. More than 90 per cent of the area under sorghum, groundnut, and pulses is rainfed. In case of maize and chickpea, 82 to 85 per cent area is rainfed. Even 78 percent of cotton area is rainfed. In case of rapeseed/mustard, about 65.8 per cent of the area is rainfed. Interestingly, but not surprisingly, 61.7, 44.0, and 35.0 per cent area under rice, barley and wheat, respectively, is rainfed.

v. The productivity of grains already showed a plateau in irrigated agriculture due to problems related to nutrient exhaustion, salinity build up and raising water table. Therefore, the challenges of the present millennium would be to produce more from drylands while ensuring conservation of existing resources. Hence, new strategies would have to be evolved which would make the fragile dryland ecosystems more productive as well as sustainable. In order to achieve evergreen revolution, we shall have to make grey areas (drylands) as green through latest technological innovations.

vi. Drylands offer good scope for development of agroforestry, social forestry, horti-sylvi-pasture and such other similar systems which will not only supply food, fuel to the village people and fodder to the cattle but forms a suitable vegetative cover for ecological maintenance.

Area and Distribution of Rainfed Agriculture

Majority of the districts in India are dry farming districts and covers 49 per cent of the net cultivated area. Most of this area is covered by crops like millets, pulses, oilseeds, cotton etc. These areas spread throughout the country i.e. Tamilnadu, Karnataka, Andhra Pradesh, Madhya Pradesh, Maharastra, Gujarat, Rajasthan, Punjab, Haryana and Uttar Pradesh.

i. Areas of low rainfall (below 750 mm) constitute more than 30 per cent of total geographical area
ii. About 84 districts in India fall in the category of low rainfall area
iii. Providing irrigation to all the drylands is expensive and takes long time
iv. Globally the area under drylands is about 6150 m.ha.
v. In India out of the total cultivated area of 139 m.ha the area under rainfed is about 67.5 m.ha, which comes to 49 percent.

Rainfed area in different regions of India

Region	States	% of rainfed area
Cold and northern region	Jammu and Kashmir,Uttaranchal and Himachal Pradesh,	60 to 81
Arid western Region	Rajasthan and Gujarat	66 to 88
Semi arid to arid central and southern region	Madhya Pradesh, Maharastra, Andhra Pradesh, Andhra Pradesh, Karnataka,Tamilnadu	76 to 82
Sub humid to humid eastern region	Eastern Uttar Pradesh, Bihar, Jharkhand, Orissa, West Bengal	33 to 73
Humid to per humid north eastern region	Assam and north eastern hill states	Up to 90

Major historical events for rainfed agriculture in India

1920- Scarcity tract development given importance by Royal Commission Agriculture

1923- Establishment of Dry Farming Research Station at Manjri

1933- Research Stations established at Bijapur and Solapur

1934- Research Stations established at Hagari and Raichur

1935- Research Station established at Rohtak

1942- Bombay Land Development act passed

1944- Monograph on dry farming in India by Kanitkar

1953- Establishment of Central Soil Conservation Board

1955- Dr Farrning Demonstration Centres started

1970- Twenty three Research Centres established under AICRPDA

1972- Establishment of ICRISAT

1976- Establishment of dryland Operational Research Projects (ORPs)

1977- Krishi Vigyan Kendra (KVK), Hyatnagar

1983- Starting 47 model watersheds under ICAR

1984- Establishment of Dry land Development Board in Karnataka and Word Bank assisted Watershed Development Programmes in four states

1985- Central Research Institute for Dry land Agriculture (CRIDA) at Hyderabad

1986- Initiated National Watershed Development Project for Rainfed Agriculture (NWDPRA) programmes in 15 states by Government of India.

2006- The Union Government has constituted a National Rainfed Area Authority (NRAA) on 3 November, 2006 to give focused attention to the problems of rainfed areas of the country.

As 49 percent of India's net sown area is comes under rainfed situation; it has a greater role in country's agricultural production. This rainfed area can be further sub-divided into specific agro-climatic condition as given below-

Rainfall (mm)	Zone	Net sown area (%)	Rainfall
<500	Arid	16	Very low
500-750	Semi-arid	17	Low
750-1100	Dry sub-humid	35	Medium
1100-1400	Moist sub-humid	24	High
>1400	Humid mountains	8	Very high

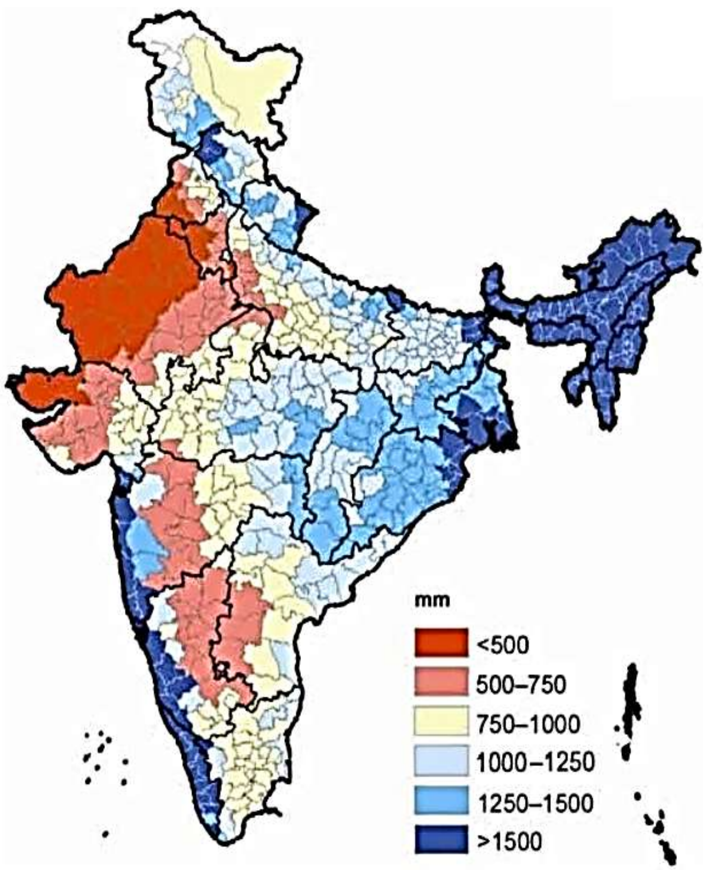

Fig. Average annual rainfall of different regions of India

Key Agricultural Statistics at a Glance - All India

S.No.	Indicator	Year	Unit	Value
	Land Use Indicators			
1	Geographical Area	2018-19	Million Hectare	328.73
2	Reported Area for Land Utilization Statistics	2018-19	Million Hectare	307.79
3	Area under Forest	2018-19	Million Hectare	72.01
4	Percentage of Area under Forest to Reported Area	2018-19	-	23.40%
5	Gross Cropped Area	2018-19	Million Hectare	197.32
6	Percentage of Gross Cropped Area to reported area	2018-19	-	64.11%
7	Net Area Sown	2018-19	Million Hectare	139.35
8	Percentage of Net Area Sown to Reported Area	2018-19	-	45.27%
9	Area sown more than once	2018-19	Million Hectare	57.97
10	Cropping Intensity (%)	2018-19	-	141.60
11	Net Irrigated Area	2018-19	Million Hectare	71.55
	(a) By canals	2018-19	Million Hectare (%)	16.43 (16.00%)
	(b) Tube-wells	2018-19	Million Hectare (%)	34.71 (33.81%)
12	Gross Irrigated Area	2018-19	Million Hectare	102.67
13	Intensity of Irrigation	2018-19	-	
	Production & Procurement Indicators			
14	Foodgrains Production (as per 4th Advance Estimates)	2020-21	Million Tonnes	308.65
	(a) Kharif	2020-21	Million Tonnes	149.56
	(b) Rabi	2020-21	Million Tonnes	159.08
15	Horticulture Production (as per 3rd Advance Estimates)	2020-21	Million Tonnes	331.05
16	Milk Production	2019-20	Million Tonnes	198.44
17	Meat Production	2019-20	Lakh Tonnes	85.99
18	Livestock Population as per 20th Livestock Census	2019	Million Numbers	536.76
19	Fish Production	2019-20	Lakh Tonnes	141.64

(Source: Agricultural Statistics at a Glance 2021 Government of India, Department of Agriculture & Farmers Welfare)

2.
PROBLEMS AND PROSPECTS OF RAINFED AGRICULTURE

Rainfall is the primary and most important factor affecting productivity in drylands and the occurrence of rainfall is mostly uncertain and erratic. About 40 % of cereals, 70 % finger millet and cotton, 90 % pulses and oil seeds and almost 100% of millets are grown on minted lands. Drylands are generally poor in productivity. Most of the crops and varieties grown in drylands are subsistence oriented with low yields. The cultivars are of longer duration, photosensitive and have a low harvest index with low response to inputs such as fertilizers. Deforestation, overgrazing and unlimited cultivation on sloping lands have increased the runoff, reduced the recharge of the soil profile and around water and caused severe soil erosion. Crop production in such area is highly marginal.

The main constraints of rainfed agriculture are as follows:

1. Basic resource constraints
2. Socio-economic constraints
3. Technological constraints

1. **Basic resource constraints:** Rainfed farms have, for centuries, been the scene of frequent drought, floods and other forms of human tragedy due to erratic rainfall pattern and other natural hazards. More than 80 of the dryland Farmers own less than 2 ha of land per capita. The drylands are characterized by uncertain and aberrant weather. Uncertainty and variability of rains, of both space and time, is the biggest constraint affecting agricultural production in rainfed fanning. Drylands are generally low in fertility. The soils are universally deficient in nitrogen and frequently in phosphorus. Potash is adequate in many cases except in light textured soils or in soils under continual high production. Problems such as soil salinity or alkalinity further aggravate the situation. The average consumption of fertilizers in cropped area of drylands is less than 10 kg/ha in the predominantly non-irrigated semiarid tropical districts. In rainfed agriculture, drought stress can occur at any time during crop growth.
2. **Socio-economic constraints:** Most of the rainfed farmers are poor and have very little cash reserve available. The total operation is of the subsistence type and the farmer's concern is to grow staple crops for home consumption. Dryland farmers are not able to utilize the credit facilities provided by the co-operatives and banks in areas where they exist because of their ignorance/low literacy rates/risk involved in farming.
3. **Technological constraints:** Lack of suitable genotypes capable of giving high and stable yields

under rainfed conditions is a major constraint. Many farmers are unable to use inputs like fertilizers, herbicides and pesticides due to lack of adequate moisture.

Prospects of rainfed agriculture

After full exploitation of dryland, it may contributes up to 75% of total food grain production. Pulses and oilseeds are mainly grown in such areas. Important commercial crops viz. Cotton, Castor, Groundnut and all coarse grains viz. Jowar, Bajra, Maize crops are rain fed. The major part of milk, meat, wool hides. bone meal etc. are also from this area.

There are three types of agriculture possible in Dry land areas viz.,

1. Crop Production
2. Animal husbandry with pastures management
3. Agro forestry.

Dry farming areas are characterized by very low and highly variable and uncertain Yields.

Problems of dryland agriculture are-

1. Inadequacy and uncertainty of rainfall and its erratic distribution. Expected rainfall in a year is 650 mm but 80% of it is received in 75-90 days of the monsoon season.
2. Late onset and early cessation of rains.
3. Prolonged dry spells during the crop period.
4. Low moisture retention capacity.
5. Poor soil fertility condition.

6. Socio-economic constraints particularly because of the pre-dominance of small and marginal farmers. 54% of the holdings is less than one hectare.
7. Technological and developmental constraints.
8. Limited infrastructure development and improper and untimely availability of credits and agricultural inputs.

The vital problem which the farmers have to face very often is to keep the crop plants alive and to get some economic returns from the crop production but the aforesaid problem is governed by a number of associated problems that are described below:

1. **Moisture stress due to scarce and uncertain rainfall:** As per definition the dry farming areas receive an annual rainfall of 500 mm or even less. The rains are very erratic, uncertain and unevenly distributed. Therefore, the agriculture becomes a sort of gamble with the nature and very often the crops have to face quite a number of climatic hazards because of which they fail all-together. The farmers also take up the farming half heartedly and used to get nominal yield. Thus water scarcity becomes a serious bottleneck in dryland agriculture.
2. **Effective storage of rain water:** According to the characteristics of dry farming either there will be no rain at all or there will be torrential rain with very high intensity. Thus in the former case the crops will have to face severe drought and in the latter case they will face either flood or water logging and they get spoiled. In case of very heavy downpour the

excess water gets lost as run-off which goes to the ponds, ditches, etc. this water could be stored for providing life saving or protective irrigation to the crops grown in dryland areas. The loss of water takes place in several ways viz., run-off, evaporation, uptake though weeds, etc. This water could be stored for short period or long period and it can be preserved either in soil, pond or ditches based on situation.

Following types of storages are required in dry tracts:

a. **Year round storage of water in soil:** From a water reservoir it is lost through Percolation, seepage, evaporation / transpiration or evapo-transpiration. For a Profitable cropping the moisture in soil should be regulated in such a way that the plants may be able to absorb it as and when they need. Therefore the water storage should be done to meet year round need of the crop. Generally dry farming areas face a serious problem of water loss because of undulating soil surface, barren lands, excessive growth of weeds in the field.

b. **Retention of moisture till need for the crops:** To meet the water requirement of the crop plants it is essential to adopt such management practices which may help in retention of moisture in the soil at least till the crop needs it. The technique of moisture retention requires special skill, care and too much expense which majority of the farmers can not fulfill. Therefore, this problem remains untackled and becomes the main reason for crop failure.

c. **Prevention of direct evaporational loss of moisture:** Evaporation is the major type of water loss from the soil or water surface. Mostly the agriculturist does not bother for this loss and after sowing the crop he does not visit the plot or the water collected in some ponds or ditches is left uncared and slowly it gets lost through evaporation. Prevention of this loss needs lot of expenses which the farmer can hardly meet and crops fail due to lack of moisture. Sometimes farmers do not do it because of their ignorance and carelessness, otherwise the collected water, if well preserved, may be used for fish raising, chest nut production, irrigation purposes, etc. and they can get best return from it.

d. **Regulation of water withdrawn by crop from soil:** The soil moisture is transpired by the crop plants at a very high rate from the soil which hardly gives any positive result. This rate of transpiration may be reduced to half or even low in certain cases and stored water may be absorbed by the plants till they need it, otherwise in surplus months they get too much moisture but in deficit months they do not get at all. This type of supply helps in a profuse growth and succulence in early growth period and wilting during reproductive growth which ultimately result into a poor yield and quality of the produce. Thus it becomes essential to adopt some practice which may help in a proper regulation of water throughout the crop growth period.

3. **Disposal of dry farming products:** In dry farming all the farmers grow similar type of crops which mature at the same time and the growers like to dispose their products soon after the harvest because due to poverty they cannot hoard or store for a longer period in anticipation for an appreciation in the market price, This results into a glut in the market and the grain traders or the middle man use to have upper hand in the deal. Thus the product is sold with a great difficulty and at poor price. Therefore, marketing becomes a serious problem in dry farming tracts.

4. **Selection of limited crops:** Only drought resistant crops viz., oil seeds, pulses and coarse grains like millets can be sown. Thus the farmers have to be satisfied with above mentioned crops and they have to purchase rest of the commodities to fulfill their household demands.

5. **Careful and judicious manurial scheduling:** In case of irrigated farming the farmers are at liberty to apply manures and fertilizers according to their availability and facility but in case of dry farming they have to be very careful in fertilizer application because due to lack of moisture broadcasting either for basal or for top-dressing becomes a wasteful and meaningless. There

can he deep placement and foliar spraying of the nutrients for an improved crop production.

6. **Utilization of preserved moisture:** Purposeful utilization of preserved water depends upon soil type, plant type and other factors. The amount of available water to the plants depends upon depth of their roots, their proliferation and density. In case of limited moisture condition the yield of the crop is directly related to their rooting depth. The rooting depth can be substantially increased by mechanical manipulation of the soil. If the planting is very dense and all the plants have same type of rooting then there will be a tough competition of roots for moisture and scarce moisture condition will result in wilting of plants. Therefore, utilization of preserved moisture is an art with which best use of moisture can be made. The water collected in ponds or brooks may be used to give protective or life saving irrigation to the crops or for raising fish or for growing chestnut along with fish culture. The widely spaced crops can be intercropped with oilseeds or pulses for increasing the productivity of land per unit area per unit time. Thus the water collected during the rainy season and stored either in soil or in some ponds need special technique and skill for its purposeful utilization.

7. **Quality of the produce:** Invariably the quality of the produce from dry farming areas is found to be inferior as the grains are not fully developed or they are not filled properly, often mixed with other crop seed due to mixed cropping system prevalent in the area and the

fodder becomes more fibrous. These all reduce the market price and the farmers do not get profit of their labour and investment.

Some of the approaches and practices to boosting crop production in drylands:

1. Determination of the effective growing season
2. Selection of suitable genotypes to match the rainfall pattern
3. Selection of an intercropping system to ensure sustainability of production and income
4. Creation of a local, cheap water source like a farm pond or a dug well
5. Using improved agriculture tools, implements and practices to achieve precision
6. Use moderate amount of nutrients
7. Water harvesting technologies
8. Good vigilance for timely control of diseases and pest
9. Crop harvestiong during physiological maturity stage

3
SOIL AND CLIMATIC CONDITIONS PREVALENT IN RAINFED AREAS

The specific climatic conditions in rainfed area can be explained as below-

A. **Variable Rainfall:** The annual rainfall varies greatly from year to year. Generally, higher the rainfall less is the coefficient of variation. In other words, crop failure due to uncertain rains arc more frequent in regions with lesser rainfall.

The rainfall of India has been considered in scarcity and drought have been pointed out as below-

1. The south-west monsoon brings the bulk of rainfall to major parts of India from June to September. The south-west monsoon has two branches, one enters India from the westcoast and other coming through the Bay of Bengal enters Burma, Bengal and Orissa.

2. The south-west monsoon is followed by another monsoon called the north-east monsoon which supplements the rainfall of the first monsoon and in some places is the main source of rainfall.
3. Winter rainfall is received in the mountainous districts of the northern India, parts of the Punjab plains and also places in the southern parts of the peninsula.
4. Spring rainfalls are received in Assam, Bengal and other parts of north-east India and in a few mountainous places in the south.
5. The general causes of rainfall have been shown to be linked up with annual rise in temperature of the land surface with the beginning of the calendar year first in the peninsular India and later in the northern India, creating low pressure areas. This produces in draught of air from the surrounding seas. Moisture-laden air currents thus arise and increase in volume and pressure with unlimited heights when they impinge against mountain barriers of the western and eastern ghats bringing continuous rainfall on the land surface and giving rise to south-west monsoon from June to September and then to north-east monsoon up to November. Where the air currents are required to ascend a barrier like a mountain, conditions favourable for greater precipitation are created by expansion and dynamic cooling of the air. Presence of local water vapour in the air helps in increasing the precipitation.
6. Winds coming over land surface from the north-west are dry and cold and are the main cause of

breaks in the monsoon, or they tend to decrease the rainfall of a tract by diluting the moisture laden masses of the atmosphere.

7. India can be divided into three distinct zones according to the character of the rainfall. viz. (1) heavy rainfall zone with rainfall above 1150 mm, (2) moderate rainfall zone with rainfall between 750 and 1150 mm, and (3) low rainfall zone receiving less than 750 mm of annual rainfall.
8. The tremendous variation in rainfall in these zones is mainly due to the geographical position of these tracts with reference to the surroundings seas and the configuration of the land surface. Other local factors like rivers, lakes and forests contribute only slightly to determine the annual rainfall.
9. It is shown that four different types of rainfall can be met with in tracts of low rainiall. viz.,
   (1) places receiving chiefly the south-west monsoon,
   (2) places receiving south-west monsoon but supplemented by equally important north- east monsoon,
   (3) places receiving mainly north-cast monsoon and
   (4) places with evenly distributed rainfall over five to six months.
10. In addition to uncertainty and meagerness of the annual rainfall, long breaks in the monsoon and desiccating factors like high winds, low humidity, bright sunshine and

high temperature contribute to failure of crops in these vast areas giving rise to periodic scarcity and famine. These areas have been called the problem areas.

B. **Intensity and Distribution:** In general, more than 50 per cent of total rainfall is usually received in 3 to 5 rainy days. Such intensity rainfall results in substantial loss of water due to surface runoff. This process also accelerates soil erosion. Distribution of rainfall during the crop growing season is more important than total rainfall in dryland agriculture.
C. **Late Onset of Monsoon:** If the onset of monsoon is delayed crops/varieties recommended to the region can not be sown in time. Delayed sowing, leads to uneconomical crop yields.
D. **Early Cessation of Rains:** This situation is equally or more dangerous than late onset of monsoon. Rainy season crops will be subjected to terminal stress leading to poor yields. Similarly, post rainy season crops fail due to inadequate available soil moisture, especially during reproductive and maturity Phases.
E. **Prolonged Dry Spells:** Breaks of monsoon for 7-10 days may not be a serious concern. Breaks of monsoon rains for more than 15 days duration especially at critical stages for soil moisture stress lead to reduction in yield. Drought due to break in monsoon may adversely affect the crops in shallow soils than in deep soils.
F. **High evaporation rates**

G. Bright solar radiation

H. Temperature & Seasonal fluctuations

Soil characteristics of rainfed area are as below-

Alluvial soils occupies largest area in raifed region. The problems are not acut in these soils as they are in black and red soils. Major problems are encountered in vertisols, aflisols and related soils. Black (vertisols), red (alfisols) and associated soils are mostly distributed in central and south India. The coastal areas have alfisols, laterite and lateritic soils.

Alfisols

These are commonly referred as red soils. The problems relating to crop production are:

a. Poor clop stand due to crusting and rapid drying of surface soil,
b. Poor crop growth due to unreliable soil moisture supply, low moisture storage capacity due to shallow depth and drought spells during crop season,
c. Low soil fertility due to low organic matter, poor nutrient status particularly with respect to N, P, S and Ca and compact subsoil layer (argillic horizon)
d. Land degradation from soil erosion and crusting.

Vertisols

These soils commonly called as black soils are characterized by high clay content (30-70%). Important constraints for crop production are:

a. Physical constraints such as narrow range of soil water content for tillage, tendency to become waterlogged and poor traffic ability,
b. Low soil fertility due to low N and available P, and
c. Land degradation from soil erosion and salt accumulation, especially in low lying areas.

Inceptisols and Entisols

These are commonly termed as alluvial soils. They have low water holding capacity and low nutrient holding capacity. Management of these soils for crop production is relatively easy compared to red and black soils. Soil erosion is, however, a problem leading to land degradation.

Some more peculiar characteristics of rainfed agriculture are-

a. **Uncertain and limited annual rainfall:** Dry farming areas are characterised by low annual rainfall and according to the definition the dry tracts are those which receive an annual rainfall of 500 mm or less. Even this much rain is not well distributed and due to that the crop production becomes very poor. The crops very often suffer from aberrant weather like delayed onset of monsoon, long gap in rainfall and early stoppage of rains.
b. **Extensive climatic hazards:** As per distribution of rains the dry farming areas used to get uneven distribution of rains i. e. sometimes intensity of rains is too much and rest of the year there is no rain at all. This leads to an accelerated run-off water and drought

respectively. Thus the area has to face flood, water-logging or drought. Since there is no facility for irrigation, therefore, the crops suffer badly from the frost also during winter. This way there are extensive climatic hazards leading to the partial or total crop failure.

c. **Undulating soil surface:** Because of improper distribution of rains there is soil erosion caused by both water and wind. During rainy season water erosion and during summer season wind erosion are noticed as in the former case there is too much of water but in the latter case the surface is completely dry. Therefore, every year soil is eroded 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.

d. **Extensive holding:** Dry farming areas use to face uncertainty of rains which are erratic and unevenly distributed resulting in crop failure either partially or completely. Under such conditions the cattle and human lives become very difficult, thus the population density is found to be very poor and villages are located at distant places, Therefore, the farmers of dry farming tracts use to have a large holding.

e. **Extensive agriculture:** The type of agriculture adopted in dryland areas always remains extensive due to lack of irrigation facilities. In such areas most of the farmers use to grow hardly one or two crops annually while in some cases the farmers use to keep fallow during rainy season with an object to conserve more moisture and to control weeds; then they grow one single rabi season crop or some farmers use to grow pigeon pea based mixed crop that takes whole year. Thus the cropping intensity remains only one hundred per cent.

f. **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 rain led area. However, bigger plots are also made in case of fully mechanized farms but the area remains Wider intensive cropping and the plots are always engaged under some or the other crop.

g. **Similar type of crops:** In case of dryland agriculture only drought resistant crops can be grown and almost all the farmers of the region use to grow similar crops like arhar, castor, millets, oilseeds, etc. 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.

h. **Lower crop yields:** Yields of various crops grown in drylands 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. Sometimes the yield becomes so low that it does not meet out the cost of its cultivation but the farmers have to do the farming because of their livelihood and they do not take the family labour into account while calculating the cost of cultivation.

i. **Poor market of the produce:** Since everyone uses to grow the same crops and they become ready for sale at the same time; hence, the farmers have to face a hard time and they get less price of their produce because of poor demand and abundant supply rather a glut in the market. Very often the people of the locality do not want to buy the commodity and the farmers fall in the grip of small grain traders who use to purchase at cheaper price and finally sell to herders. Thus the farmers do make any profit.

j. **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 stall-fed, they are loose and depend on grazing. The poor economy of the farmers affects their education, brought up of children and productivity of the cattle.

k. **Widespread deficiency diseases in human beings:** Surplus of low calorie 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. The most important example is: consumption of Lathyrus pulse in place of Arhar pulse in rain fed areas cause lathirism in people. Lathyrus grows very vigorously and farmers get plenty of it to feed their cattle and people, though its production is banned by the Government. Likewise many other diseases are found common in such areas.

4.
SOIL AND WATER CONSERVATION TECHNIQUES IN RAINFED AREAS

Soil and water conservation techniques can be broadly classified as-

1. *In-situ* soil moisture conservation practices
2. Mechanical / Engineering measures
3. Forestry Measures
4. Agrostological Measures

1. *In-situ* soil moisture conservation practices

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

A. **Ridges and furrows:** The field must be formed into ridges and furrows. Furrows of 30-45 cm width and 15-20 cm height are formed across the slope. The furrows guide runoff water safely when rainfall intensity is high and avoid water stagnation. They collect and store water when rainfall intensity is less. It is suitable for medium deep to deep black soils and deep red soils. It can be practiced in wide row spaced crops like cotton, maize, chillies, tomato etc. It is not suitable for shallow red soils, shallow black soils and sandy/ gravelly soils. It is not suitable for broadcast sown crops and for crops sown at closer row spacing less than 30 cm. Since furrows are formed usually before sowing, sowing by dibbling or planting alone is possible.
B. **Tied ridging:** It is a modification of the above system of ridges and furrows wherein the ridges are connected or tied by a small bund at 2-3 m interval along the furrows to allow the rain water collection in the furrows which slowly percolated in to the soil profile
C. **Broad bed furrows (BBF):** This practice has been recommended by ICRISAT for vertisols or black soils in high rainfall areas (> 750 mm). Here beds of 90-120cm width, 15 cm height and convenient length are formed, separated by furrows of 60 cm width and 15 cm depth. When runoff occurs, its velocity will be reduced by beds and infiltration opportunity time is increased. The furrows have a gradient of 0.6%. Crops are sown on the broad beds and excess water is drained through number of small furrows which may be connected to farm ponds. It can be formed by bullock drawn or tractor drawn implements. Bed former cum seed drill enables BBF

formation and sowing simultaneously, thus reducing the delay between receipt rainfall and sowing. Broad bed furrow has many advantages over other methods as given below-

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

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

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

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

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

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

Ridges and Furrow

Tied Ridging

Broad Bed and Furrows

Compartmental Bunding

Scooping

Contour Bunding

2. Mechanical / Engineering measures

When Agronomic measures alone are not adequate, mechanical measures are to be adopted to supplement the agronomic measures. Mechanical measures usually involve construction of mechanical barriers across the direction of flow of rainwater to retard or retain runoff and thereby reduce soil and water loss.

The mechanical measures include:

A. Contour bunding
B. Graded bunding
C. Bench terracing
D. Gully control / plugging
E. Vegetative barriers

A bund or terrace is an earthen embankment or a depression or a combination of both constructed across the land slope to control runoff and minimize soil erosion by reducing the length of slope. By reducing the slope, the velocity of runoff is not allowed to attain critical value, which initiates scouring.

A. Contour bunding: It is most popular in the country. Contour bunding consists of narrow based trapezoidal bunds on contours to impound runoff water behind them so that it can gradually infiltrate into the soil for crop use. Contour bunding is generally recommended for areas receiving <600 mm rainfall (low rainfall areas) and for permeable soils up to slopes of about 6%.Spacing between two bunds is commonly expressed in terms of the V.I.(vertical interval) which is the difference in elevation between two similar points on two consecutive bunds.

The following formula is used for determining spacing of bunds

$$V.I. = S/a + b$$

where,

V.I.= vertical interval (m) between consecutive bunds

S = % slope of land

'a' and 'b' constants depends on soil and rainfall characteristics

The height of the contour bunds depends on slope of land, spacing of bunds and maximum intensity expected. In deep black soils, contour bunds have been a failure due to cracking of bunds during dry months and water stagnation above the bunds for prolonged periods during rainy season.

B. Graded bunding: Graded bunds or channel terraces are constructed in high rainfall areas of >600 mm where excess water has to be removed safely of the field to avoid water stagnation. In case of highly impermeable soils like deep black soils graded bunds are recommended even in lesser rainfall area (500 mm). Water flows in graded channels constructed on upstream side of bunds at non-erosive velocities and is led to safe outlets or grassed waterways. Channel portion of the graded bunds is put under cultivation and the grassed waterways are permanently kept under grass.

C. Bench terracing: Bench terracing is practiced in steep hill slopes, where mere reduction of slope length is not adequate for reducing the intensity of scouring action of runoff flowing down. In addition to slope length reduction, the degree of slope is also reduced. Bench terracing consists of transforming relatively steep land into a series of level strips or platforms across the slope to reduce the slope length and consequently erosion. The field is made into a series of benches by excavating soil from upper part and filling in the lower part of terrace. It is normally practiced on slopes > 14% i.e. from 16 to 33%. Depending on soil, climate and crop requirements bench terraces may be table top or level, sloping outwards or sloping inwards.

Type of bench terrace	Suitability
Table top or level terraces	Suitable for medium rainfall areas (750mm) with even distribution and highly permeable deep soils.
Sloping outwards terraces	Constructed in low rainfall areas (<750 mm) with permeable soils of medium depth.
Sloping inwards terraces	Constructed in heavy rainfall areas (>750 mm) and soils with poor infiltration rate.

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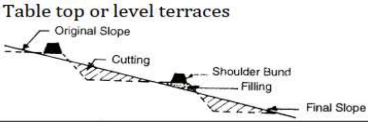
<tr><th>Type of bench terrace</th><th>Suitability</th></tr>
<tr><td>Table top or level terraces

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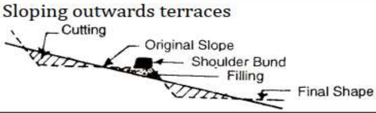
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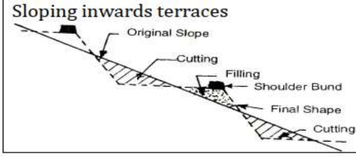

</td><td>Constructed in heavy rainfall areas (>750 mm) and soils with poor infiltration rate.</td></tr>
</table>

D. **Gully control:** Gullies the result of sheet and rill erosion left unchecked. The basic approach to gully control involves reduction of peak flow rates through the gully and provision of channel for the runoff water. Agronomic measures of soil conservation like contour cultivation, strip cropping, cover crops, mulching etc., aid in reducing the peak flow rates through gullies. The provision of the stable channel for the flow that must be handled is accomplished by stabilizing the gully sides and bed by establishing vegetation. Temporary structures such as brush check wood dams, loose rock dams, rock fill dams and woven wire dams, and permanent structures such as chute spill ways, drop spill ways, concrete check dams and pipe spill ways are practiced for reducing channel gradient to maintain velocities below erosive level.

E. **Vegetative barriers:** These are the rows of closely planted grass or shrub along the contours for erosion control in Agricultural lands. They check the velocity of runoff and retain the sediment by acting as barrier to runoff. Khus Khus (*Vetiveria zyzynoides*) is the most recommended plant for this purpose.

F. **Grassed waterways:** These are drainage channels either developed by shaping the existing drainage ways or constructed separately for effecting drainage of agricultural lands. They are used to handle runoff, discharge from graded bunds, broad base terraces and bench terraces.

Benefits of grassed waterways-

i. Provide drainage to agricultural lands
ii. Convert unstable channels or gullies into stable channels by providing grass cover
iii. For leading water at non erosive velocity into farm ponds

Grassed water ways are normally dug to a shallow depth of 0.15 to 0.5 m. They are constructed one or two seasons ahead of the construction of channel terraces.

3. Forestry Measures

Forest lands are usually found at higher elevations where the slopes are steepest, soils are less stable and easily eroded and precipitation is heavy. The leaves and branches of trees and shrubs intercept the rain and reduce the impact of raindrops. Contour trenching and aforestation is recommended for improving the productivity of forests. Contour trenching is done by excavating a trench along the contour and forming soil bank. Rain water thus held up in these trenches for some time and facilitate the growth of vegetation. Plants are sown in trenches taking advantage of water. Tree species suitable are *Pinus patula, Pinus kesia, Acacia nilotica, Eucalyptus camaldulensis* etc.

4. Agrostological Measures

Grasses prevent erosion by intercepting rainfall and by their binding power of the soil particles. A grass-legume association is ideal for soil conservation. Legumes build up soil fertility by fixing atmospheric N in root nodules. Grasses have several uses in soil conservation like:

i. Stabilizing the surfaces of water ways, contour bunds and front faces of bench terraces

ii. Stabilizing the gully slopes and sides
iii. Preventing wind erosion

The desirable characters of grasses for soil conservation are:

Should be perennial
Drought resistant
Develop good canopy
Deep root system
Prostate growth habit
Less palatable to cattle
Useful for cottage industries

Useful grasses: *Cenchrus ciliaris, Chloris guyana, Cynodon dactylon, Dicanthium annulatum, Heteropogan contortus, Iseilema laxum, Panicum antidotale*

Legumes: *Atylosia scarbaceoides, Centrosema pubescence, Stylosanthus hamata*,

Grass + legume: *Cenchrus ciliaris + Stylosanthus hamata*

5.
DROUGHT

Concept of drought:

The word drought generally denotes scarcity of water in a region. It is generally a temporary condition that occurs for a short period due to deficient precipitation for vegetation, river flow, water supply and human consumption.

Definition:

a. Early workers defined drought as prolonged period without rainfall.
b. According to Ramdas (1960) drought is a situation when the actual seasonal rainfall is deficient by more than twice the mean deviation.
c. American Meteorological Society defined drought as a period of abnormally dry weather sufficiently prolonged for lack of water to cause a severe hydrological imbalance in the area affected.
d. Prolonged deficiencies of soil moisture adversely affect crop growth indicating incidence of

agricultural drought. It is the result of imbalance between soil moisture and evapotranspiration needs of an area over a fairly long period so as to cause damage to standing crops and to reduce the yields.

e. The irrigation commission of India defines drought as a situation occurring in any area where the annual rainfall is less than 75% of normal rainfall.

Classification of drought

Drought can be classified based on duration, nature of users, time of occurrence and using some specific terms.

1. Based on duration

a. 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 crop season.

b. Seasonal drought: This is found in climates with well defined rainy and dry seasons. Most of the arid and semiarid zones fall in this category. Duration of the crop varieties and planting dates should be such that the growing season should fall within rainy season.

c. Contingent drought: This involves an abnormal failure of rainfall. It may occur almost anywhere especially in most parts of humid or sub humid climates. It is usually brief, irregular and generally affects only a small area.

d. Invisible drought: This can occur even when there is frequent rain in an area. When rainfall is inadequate to meet the evapo-transpiration losses, the result is borderline water deficiency in soil resulting in less than optimum yield. This occurs usually in humid regions.

2. Based on relevance to the users (National Commission on Agriculture, 1976)

a. Meteorological drought: It is defined as a condition, where the annual precipitation is less than the normal over an area for prolonged period (month, season or year).

b. Atmospheric drought: It is due to low air humidity, frequently accompanied by hot dry winds. It may occur even under conditions of adequate available soil moisture. It refers to a condition when plants show wilting symptoms during the hot part of the day when transpiration exceeds absorption temporarily for a short period. When absorption keeps pace with transpiration the plants revive (Mid day wilt).

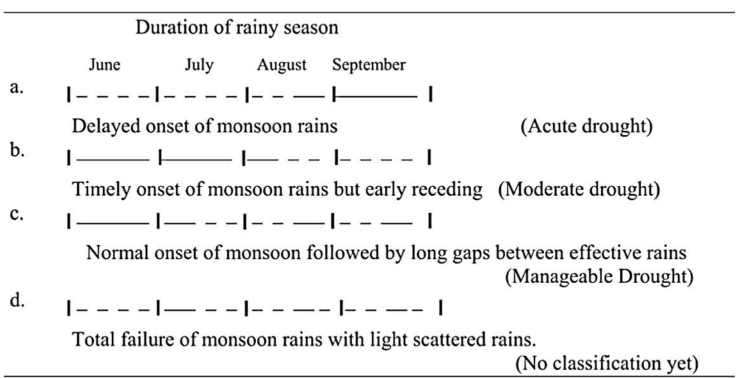
c. Hydrological drought: Meteorological drought, when prolonged results in hydrological drought with depletion of surface water and consequent drying of reservoirs, tanks etc. It results in deficiency of water for all sectors using water. This is based on water balance and how it affects irrigation as a whole for bringing crops to maturity.

d. Agricultural drought (soil drought): It is the result of soil moisture stress due to imbalance between available soil moisture and evapotranspiration of a crop. It is usually gradual and progressive. Plants can therefore, adjust at least partly, to the increased soil moisture stress. This situation arises as a consequence of scanty precipitation or its uneven distribution both in space and time.

Relevant definition of agricultural drought appears to be a period of dryness during the crop season, sufficiently prolonged to adversely affect the yield. The extent of yield loss depends on the crop growth stage and the degree of stress. It does not begin when the rain ceases, but actually commences only when the plant roots are not able to obtain the soil moisture rapidly enough to replace evapotranspiration losses.

Delayed onset of S–W monsoon rains or early receding of monsoon rains towards half way of the season or long gaps between two heavy and effective rains during rainy season are the general phenomenon of agricultural drought in India (Fig. below).

Probable abnormal monsoon conditions in India



3. Based on time of occurrence

a. Early season drought: It occurs due to delay in onset of monsoon or due to long dry spells after early sowing

b. Mid season drought: Occurs due to long gaps between two successive rains and stored moisture becoming insufficient during the long dry spell.

c. Late season drought: Occurs due to early cessation of rainfall and crop water stress at maturity stage.

Other terms to describe drought

a. 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; eg. A condition may be a drought situation for growing rice, but the same situation may not be a drought for growing groundnut.

b. Physiological drought: Refers to a condition where crops are unable to absorb water from soil even when water is available, due to the high osmotic pressure of soil solution due to increased soil concentration, as in saline and alkaline soils. It is not due to deficit of water supply.

Causes for agricultural drought:

a. Inadequate precipitation
b. Erratic distribution
c. Long dry spells in the monsoon
d. Late onset of monsoon
e. Early withdrawal of monsoon
f. Lack of proper soil and crop management

Drought– prone area in India:

Drought– prone areas are identified based on moisture index; which is computed using the data of annual precipitation (P) and the annual water need (PET) as per the following formula given by Thornthwaite and Mather (1955);

Moisture Index= (P–PET)/PET × 100

Moisture index	Climatic zone	Per cent area of India
<–66.7	Arid	19.6
–66.7 to –33.3	Semi-arid	34.0
–33.2 to 0	Dry sub-humid	21.1
0 to + 20	Moist sub-humid	10.2
+20.1 to + 99.9	Humid	7.8
> + 100	Per-humid	8.3

Effect of drought on morpho- physiological parameters in crop

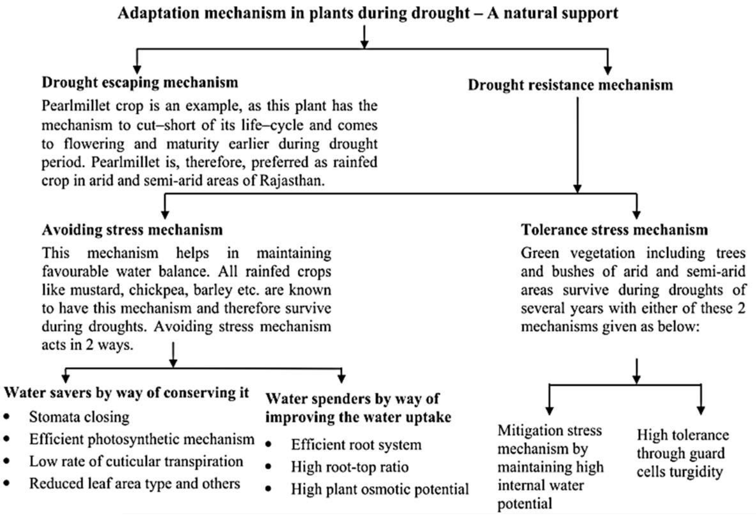
1. Water relations: Alters the water status by its influence on absorption, translocation and transpiration. The lag in absorption behind transpiration results in loss of turgor as a result of increase in the atmospheric dryness.
2. Photosynthesis: Photosynthesis is reduced by moisture stress due to reduction in Photosynthetic rate, chlorophyll content, leaf area and increase in assimilates saturation in leaves (due to lack of translocation).
3. Respiration: Increase with mild drought but more serve drought lowers water content and respiration.
4. Anatomical changes: Decrease in size of the cells and inter cellular spaces, thicker cell wall, greater development of mechanical tissue. Stomata per unit leaf tend to increase.
5. Metabolic reaction: All most all metabolic reactions are affected by water deficits.
6. Hormonal Relationships: The activity of growth promoting hormones like cytokinin, gibberlic acid and

indole acetic acid decreases and growth regulating hormone like abscisic acid, ethylene, etc., increases.

7. Nutrition: The fixation, uptake and assimilation of nitrogen is affected. Since dry matter production is considerably reduced the uptake of NPK is reduced.
8. Growth and Development: Decrease in growth of leaves, stems and fruits. Maturity is delayed if drought occurs before flowering while it advances if drought occurs after flowering.
9. Reproduction and grain growth: Drought at flowering and grain development determines the number of fruits and individual grain weight, respectively. Panicle initiation in cereals is critical while drought at anthesis may lead to drying of pollen. Drought at grain development reduces yield while vegetative and grain filling stages are less sensitive to moisture stress.
10. Yield: The effect on yield depends hugely on what proportion of the total dry matter is considered as useful material to be harvested. If it is aerial and underground parts, effect of drought is as sensitive as total growth. When the yield consists of seeds as in cereals, moisture stress at flowering is detrimental. When the yield is fibre or chemicals where economic product is a small fraction of total dry matter moderate stress on growth does not have adverse effect on yields.

Crop adaptations to drought condition:

The ability of crop to grow satisfactorily under water stress is called drought adaptation. Adaptation is structural or functional modification in plants to survive and reproduce in a particular environment.



Drought mitigation

Drought is a natural hazard, it has a slow onset, and it evolves over months or even years. It may affect a large region and causes little structural damage. The impacts of drought can be reduced through preparedness and mitigation. The components of a drought preparedness and mitigation plan are the following:

1. Prediction: Prediction can benefit from climate studies which use coupled ocean/ atmosphere models, survey of snow packs, anomalous circulation patterns in the ocean and atmosphere, soil moisture, assimilation of remotely sensed data into numerical prediction models, and knowledge of stored water available for domestic, stock, and irrigation uses.
2. Monitoring: Monitoring exists in countries which use ground-based information such as rainfall, weather, crop conditions and water availability. Satellite observations complement data collected by ground

systems. Satellites are necessary for the provision of synoptic, wide-area coverage.

3. Impact assessment: Impact assessment is carried out on the basis of land-use type, persistence of stressed conditions, demographics and existing infrastructure, intensity and areal extent, and its effect on agricultural yield, public health, water quantity and quality, and building subsidence.
4. Response: Response includes improved drought monitoring, better water and crop management, augmentation of water supplies with groundwater, increased public awareness and education, intensified watershed and local planning, reduction in water demand, and water conservation.

Drought preparedness and mitigation can be accomplished with- Soil and Water Conservation: Conservation practices minimize the disruption of the soil's structure, composition and natural biodiversity, thereby reducing erosion and soil degradation, surface runoff, and water pollution. It can be achieved by agronomic measures (Crop rotation; Contoured row crops; Terracing; Tillage practices; Erosion-control structures; Water retention and detention structures; Windbreaks and shelterbelts; contour farming, off-season tillage, deep tillage, mulching and providing vegetative barriers on the contour; etc.) and also with engineering measures (Contour bunds, trenches and stone walls; Check dams and other gully-plugging structures; Percolation ponds; Rainwater harvesting at building roofs and within field. (These technologies already has been discussed in Chapter no. 4)

6.
WATER HARVESTING

Rainwater is the key input in dryland agriculture. In a tropical country such as India which experiences extreme variation in rainfall both in space and time, rain water management assumes vital importance in cutting down risks and stabilizing crop production in dry areas. When rains are received with an intensity far reaching infiltration rate, runoff is inevitable. It varies from 10 to 40% of total rainfall. Of this at least 30% can be harvested into water storage structures.

Water Harvesting

The process of runoff collection during periods of peak rainfall in storage tanks, ponds etc., is known as water harvesting. It is a process of collection of runoff water from treated or untreated land surfaces/ catchments or roof tops and storing it in an open farm pond or closed water tanks/reservoirs or in the soil itself (in situ moisture storage) for irrigation or drinking purposes.

Runoff farming and rainwater harvesting agriculture are synonymous terms, which imply that farming is done in dry areas by means of runoff from a catchment. Runoff farming is basically a water harvesting system specially designed to provide supplemental or life saving irrigation to crops, especially during periods of soil moisture stress. Collecting and storing water for subsequent use is known as water harvesting. It is a method to induce, collect, store and conserve local surface runoff for agriculture in arid and semiarid regions.

All water harvesting systems have three components viz., the catchment area, the storage facility and the command area. The catchment area is the part of the land that contributes the rain water. The storage facility is a place where the runoff water is stored from the time it is collected until it is used. The command area is where water is used.

Water harvesting is done both in arid and semi-arid regions with certain differences. In arid regions, the collecting area or catchment area is substantially in higher proportion compared to command area. Actually, the runoff is induced in catchment area in arid lands whereas in semi-arid regions, runoff is not induced in catchment area, only the excess rainfall is collected and stored. However, several methods of water harvesting are used both in arid and semiarid regions.

Inducing Runoff

Rain water harvesting is possible even in areas with as little as 50 to 80 mm average annual rainfall. Ancient desert dwellers harvested rain by redirecting the water running down the slopes into fields or cisterns. This small amount of runoff collected over large area may be useful for supplying water to small villages, households, cattle etc., For collection of higher amount of rainfall, runoff is induced either by land alteration or by chemical treatment.

a) Land Alterations: Clearing away rocks and vegetation and compacting the soil surface can increase runoff. However, land alteration may lead to soil erosion except where slope is reduced. When erosion is not excessive and low cost hill side land is available, land alteration can be very economical way to harvest rain water in arid lands.

b) Chemical Treatment: A promising method for harvesting rain water is to treat soils with chemicals that fill pores or make soil repellant to water. Some materials used for this purpose are sodium salts of silicon, latexes, asphalt and wax.

Methods of Water Harvesting

For Arid Regions

The catchment area should provide enough water to mature the crop, and the type of farming practiced must make the best use of water. In general, perennial crops are suitable as they have deep root systems that can use runoff water stored deep in the soil which is not lost through evaporation.

a) Water Spreading: In arid areas, the limited rainfall is received as short intense storms. Water swiftly drains into gullies and then flows towards the sea. Water is lost to the region and floods caused by this sudden runoff can be devastating often to areas otherwise untouched by the storm. Water spreading is a simple irrigation method for use in such a situation. Flood waters are deliberately diverted from their natural courses and spread over adjacent plains. The water is diverted or retarded by ditches, dikes, small dams or brush fences. The wet flood plains or valley floods are used to grow crops.

b) Microcatchments: A plant can grow in a region with too little rainfall for its survival if a rain water catchment basin is built around it. At the lowest point within each microcatchment, a basin is dug about 40 cm deep and a tree is planted in it. The basin stores the runoff from microcatchment.

c) Traditional water harvesting systems: Tanka, nadi, khadin are the important traditional water harvesting systems of Rajasthan. Tanka is an underground tank or cistern constructed for collection and storage of runoff water from natural catchment or artificially prepared catchment or from a roof top. The vertical walls are lined with stone masonary or cement concrete and the base with 10 cm thick concrete. The capacity of the tank ranges from 1000 to 6,00,000 l, Nadi or village pond is constructed for storing water from natural catchments. The capacity of nadis ranges from 1200 m3 to 15000 m3- .Khadin is unique land use system where in run off water from rocky catchments are collected in valley plains during rainy season. Crops are grown in the winter season after water is receded in shallow pond on the residual moisture.

For Semiarid Regions

Water harvesting techniques followed in semi-arid areas are numerous and also ancient.

a) Dug Wells: Hand dug wells have been used to collect and store underground water and this water is lifted for irrigation. The quality of water is generally poor due to dissolved salts.

b) Tanks: Runoff water from hill sides and forests is collected on the plains in tanks. The traditional tank system has following components viz., catchment area, storage tank, tank bund, sluice, spill way and command area. The runoff water from catchment area is collected and stored in storage tank on the plains with the help of a bund. To avoid the breaching of tank bund, spillways are provided at one or both the ends of the tank bund to dispose of excess water. The sluice is provided in the central area of the tank bund to allow controlled flow of water into the command area.

c) Percolation Tanks: Flowing rivulets or big gullies are obstructed and water is ponded. Water from the ponds percolates into the soil and raises the water table of the region. The improved water level in the wells lower down the percolation tanks are used for supplemental irrigation

Fig. Percolation tank

d) Farm Ponds: These are small storage structures for collection and storage of runoff water. Depending upon their construction and suitability to different topographic conditions farm ponds are classified as Excavated farm ponds suitable for flat topography Embankment ponds for hilly terrains and Excavated cum Embankment ponds There are three types of excavated farm ponds – square, rectangular and circular. Circular ponds have high water storage capacity. Farm ponds of size 100 to 300 m3 may be dug to store 30 per cent of runoff. The problem associated with farm ponds in red soils 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 dispersants and soil-cement mixture. Bentonite has excellent sealing properties if kept continuously wet, but cracks develop when dried. Soil-cement mixture can be used. 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 a mixture of red soil and black soil in the ratio of 1: 2.

In arid and semi-arid regions, rains are sometimes received in heavy down pours resulting in runoff. The runoff event ranges from 4 to 8 during the rain season in arid and semi-arid region. The percentage of runoff ranges from 10 to 30% of total rainfall. The size of the farm pond depends on the rainfall, slope of the soil and catchment area. The dimensions may be in the range of 15 m x 15 m x 2.5 m (small size); 35 x 30 x 3 m (medium); 50 x 35 x 3 m (large). The side slope 1.5: 1 is considered sufficient. A silt trap is constructed with a width of slightly higher than the water course and depth of 0.5 to 1 m and with side slope of 1.5: 1.

The different types of lining materials are soil-cement, red and black soils, cement-concrete, bricks, Kadapa slabs, stone pitching, polythene sheet etc.,

Fig. Farm Pond Lined with Kadapa Slabs

Fig . Farm Pond lined with Cement Bricks

Fig. Farm Pond Lined with Fire Bricks

7.
WATERSHED MANAGEMENT

Soil, water and vegetation are the three important natural resources. As these resources are interdependent there is a need to have a unit of management for most effective and useful management of these resources. In this context, watershed is an important unit for the management of the natural resources

Concept of watershed management

A watershed is defined as any spatial area from which runoff from precipitation is collected and drained through a common point or outlet. In other words, it is a land surface bounded by a divide, which contributes runoff to a common point. It is defined as unit of area, which covers all the land, which contributes runoff to a common point. It is synonymous with a drainage basin or catchment area. The basic unit of development is a watershed, which is a manageable hydrological unit. The watershed is also known as ridgeline in U.K.

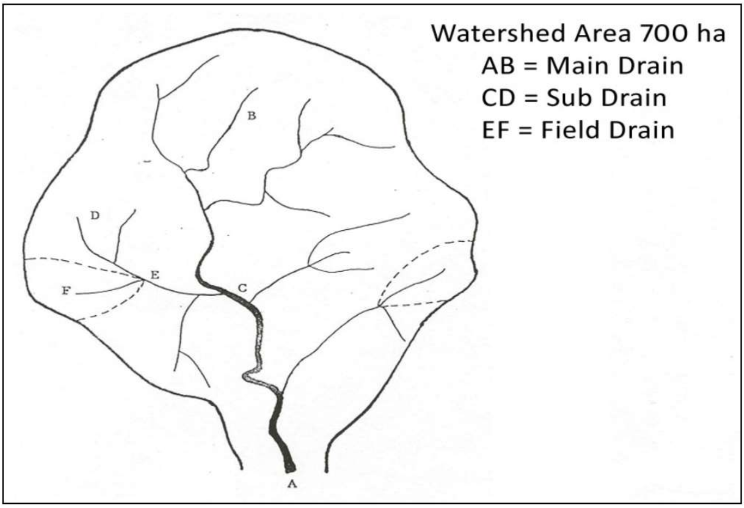


Fig. watershed

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. It is essential to have various developmental programmes on watershed basis in conjunction with basic soil and water conservation measures. The developmental activities need to be taken up from ridgeline to outlet point (ridge to valley). Watershed management programme in drylands aimed at optimizing the integrated use of land, water and vegetation in an area for providing an answer to alleviate drought, moderate floods, prevent soil erosion, improve water availability and increase food, fodder, fuel and fibre on sustained basis.

Watershed management implies the wise use of soil and water resources within a given geographical area so as to enable sustainable production and to minimize floods.

Watershed management is the rational utilization of land and water resources for optimum production with minimum hazard to natural resources. Watershed management has been taken up under different programmes launched by Government of India . The Drought Prone Area Development Programme (DPAP) and the Desert Development Programme (DDP) adopted watershed development approach in 1987. The Integrated Watershed Development Project (IWDP) taken up by the National Wasteland Development Board (NWDB) in 1989 also aimed at development of wastelands on watershed basis. The fourth major programme based on watershed concept is the National Watershed Development Programme for Rainfed Areas (NWDPRA) under the ministry of Agriculture . The ministry of Rural development funds watershed development schemes under DDP, DPAP and IWDP.

Based on the size the watersheds may be classified as-

Micro watersheds: The size of the watershed range from few hectares to hundreds of hectares. These can be designed within the crop fields.

Small watersheds: The watershed has few thousands of hectares as drainage area.

Large watersheds: The river basins are considered as large watersheds.

Another classification given by VP Singh in his book "Elementary Hydrology"-

SN	Size of watershed (ha)	Class
1.	10- 100	Mini watershed
2.	100- 1000	Micro watershed
3.	1000- 10000	Mili watershed
4.	10000- 50000	Sub watershed
5.	50000-200000	Watershed

Principles of watershed management

1. Utilizing the land based on its capability
2. Protecting the fertile top soil
3. Minimizing the silting up of the reservoirs and lower fertile lands
4. Protecting vegetative cover throughout the year
5. In-situ conservation of rain water
6. Safe diversion of surface runoff to storage structures through grassed water ways
7. Stabilization of gullies and construction of check dams for increasing ground water recharge.
8. Increasing cropping intensity through inter and sequence cropping.
9. Alternate land use systems for efficient use of marginal lands
10. Water harvesting for supplemental irrigation
11. Ensuring sustainability of the ecosystem
12. Maximizing farm income through agricultural related activities such as dairy poultry, sheep, and goat farming
13. Improving infrastructural facilities for storage transport and agricultural marketing Setting up of small scale agro industries and Improving socio-economic status of farmers.

Objectives of watershed management

The term watershed management is synonymous with soil and water conservation with the difference that emphasis is on flood protection and sediment control besides maximizing crop production. The watershed aims ultimately at improving standards of living of common people in the basin by increasing their earning capacity, by offering facilities such as electricity, drinking water, irrigation water, freedom from fear of floods, drought etc.,

The objectives are

1. Recognition of watershed as a unit for development and efficient use of land according to land capabilities
2. Flood control through small multipurpose reservoirs and other water storage structures at the headwater of streams and problem areas.
3. Adequate water supply for domestic, agricultural and industrial needs
4. Reduction of organic, inorganic and soil pollution
5. Efficient use of natural resources for improving agriculture and allied occupations so as to improve socio- economic conditions of the local residents and
6. Expansion of recreation facilities such as picnic and camping sites.

The objectives of watershed management programme can also be described in symbolic form by the expression: POWER. Here the letters symbolize the following:

P = Production of food-fodder-fuel-fruit-fibre-fish-milk combined on sustained basis
Pollution control
Prevention of floods

O = Over exploitation of resources to be minimized by controlling excessive biotic interferences like over grazing
Operational practicability of all on farm operations and follow up programmes including

easy approachability to different locations in watershed

W = Water storage at convenient locations for different purposes

Wild animal and indigenous plant life conservation at selected places

E = Erosion control

Ecosystem safety

Economic stability

Employment generation

R = Recharge of ground water

Reduction of drought hazards

Reduction of siltation in multipurpose reservoirs

Recreation

Action plan for watershed development (steps in watershed management)

1. Identification and selection of watershed: The boundary of the watershed has to be marked by field survey starting from the lowest point of the water course and proceeding upwards to the ridge line. The area may vary as low as 100 ha to as high as 10000 ha.
2. Description of watershed: Basic information has to be collected on Location, Area, shape and slope, Climate, Soil - geology, hydrology, physical, chemical and biological properties, erosion level, Vegetation-native and cultivated species, Land capability, Present land use pattern, Crop pattern, cropping system and management, Farming system adopted, Economics of

farming, Man power resource, Socio economic data, Infrastructural and institutional facilities

3. Analysis of problems and identification of available solutions

4. Designing the technology components

   a. Soil and moisture conservation measures
   b. Run off collection, storage and recycling
   c. Optimal land use and cropping system
   d. Alternate land use system and farming system
   e. Other land treatment measures
   f. Development of livestock and other allied activities
   g. Ground water recharge and augmentation

5. Preparation of base maps of watershed: incorporating all features of geology, hydrology, physiography, soil and proposed development measures for each part of watershed.

6. Cost-benefit analysis: to indicate estimated cost of each component activity, total cost of project and expected benefit.

7. Fixing the time frame: to show time of start, duration of project, time frame for completion of each component activity along with the department / agency to be involved in each component activity

8. Monitoring and evaluation: to assess the progress of the project and to suggest modification if any

9. On-farm research: to identify solutions for site-specific problems.

10. Organizational requirement: Crucial component of watershed development project is the organization.

Land use problems can only be tackled in close association with owners. As such local people should be involved in the project. To promote such an interaction the size of watershed should be 300-500 ha at micro level and a cluster of about 10 such watersheds could be managed by a single organizational unit. Watershed development agency at unit level may be an ideal organization for implementing the project. Since no project can be successful without people's participation, the watershed development agency should incorporate selected representatives of the local people. The organizational requirement include

a. Water shed development agency with multidisciplinary staff
b. Training to personnel
c. Training to farmers
d. Credit institution
e. Farmers forum /village association
f. Non governmental organization

Components of watershed management programme

The main components of watershed programme are:

1. Soil and water conservation
2. Water harvesting
3. Crop management and
4. Alternate land use systems

Soil and water conservation measures

These measures coupled with water harvesting help to improve the moisture availability in the soil profile and surface water availability for supplemental irrigation. Based on the nature and type of hydraulic barriers and their cost the conservation measures in arable lands can be divided into three categories:

a. Permanent treatments (Hardware treatments)
b. Semi permanent treatments (medium software treatments) and
c. Temporary treatments (software treatments).

a. Permanent measures: These measures are provided for improvement of 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.

Waterways: both with and without vegetation- grassed waterways for safe disposal of runoff water.

contour bunds: Suitable for low rainfall areas (< 600 mm) and in permeable soils having slope up to 6%.

Graded bunds: Suitable for high rainfall areas (> 600 mm) and for poor permeable soils having 2-6% slope

Bench terracing: suitable for soils having slopes 16 to 33%. Bench terraces reduce both slope length and degree of slope.

b. Semi permanent measures: These are usually interbund treatments where field sizes are large in conventionally bunded area. They are adopted to minimize the velocity of overland flow. These measures may lost for 2 to 5 years.

Small section / key line bunds: A small section bund may be created across the slope at half of the vertical bund spacing, which needs to be renovated at an interval of 2-3 years.

Strip Levelling: Levelling of about 4 to 5 m strips of land above the bund across the major land slope help in reducing the velocity of surface flow. Strip levelling can be done by running blade harrow at an interval of 2 to 4 years.

Live beds: One or two live beds of 2-3 m width on contour or on grade also serve the purpose. The vegetation on the beds may be annual or perennial or both.

Vegetative or live barriers: One or two barriers of close growing grasses or legumes along the bund and at mid length of slope can filter the runoff water or slow down over land flow. Khus grass is widely recommended as vegetative barrier.

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

Water harvesting: Discussed in previous chapter.

Crop management

Location specific package of practices for dryland crops have been developed by dryland research centres and state agricultural universities for all the crops and cropping systems which include-

a. Selection of crops and cropping systems to suit length of growing season
b. Optimum sowing time
c. Fertilizer schedules and balanced use of plant nutrients for crops and cropping systems

d. Weed management and package of practices for aberrant weather
e. Contingent cropping

8. CONTINGENT CROP PLANNING FOR ABERRANT WEATHER CONDITIONS

Effect of aberrant weather conditions on crops

Rainfall behaviour in dry farming areas is erratic and uncertain. The deviations in rainfall behaviour commonly met with in dry areas include delayed onset, early withdrawal and intermediary dry spells during rainy season. The adverse effect of these rainfall aberrations on crop growth vary with the degree of deviation and the crop growth stage at which such deviations occur (Table 1).

Suitable manipulations in crop management practices are needed to minimize such adverse effects of abnormal rainfall behaviour. These management decision, constitute contingency planning. Such management practices done after crop establishment and in the middle of crop growth are called mid season or mid term corrections.

Table 1 Effect of rainfall aberrations on crops

Rainfall aberration	Effect on crops
Delay in onset of rainfall	Length of cropping season or cropping duration is reduced - crop sowing is delayed
Early withdrawal or cessation of rainfall	Moisture stress at maturity grain filling is affected (terminal stress)
Intermediate dry spells	
a. Immediately after sowing	Germination will be affected, plant population will be reduced
b. At vegetative phase	Affects stem elongation, leaf area expansion, branching or tillering
c. At flowering	Affects anthesis and pollination, grain / pod number is reduced
d. At ripening	Grain filling and grain size reduced

Contingency cropping

Contingency cropping is growing of a suitable crop in place of normally sown highly profitable crop of the region due to aberrant weather conditions. In dryland agriculture, contingency of growing another crop in place of normally grown crop arises due to delay in the onset of monsoon. Depending upon the date of receipt of rainfall, crops are selected. It is assumed that the rainfall for the subsequent period isnormal and depending upon the economic status of the farmer, certain amount of risk is taken to get good profits if season is normal or better than normal.

Contingency cropping is highly location specific due to variation in amount and distribution of rainfall. Especially in arid regions, the spatial distribution of rainfall is highly variable. It is common to observe that rainfall received varies from field to field in the same location. Temperature gradually falls from August onwards reaching minimum in November and December. Contingency plan and midterm corrections vary with the type and time of occurrence of rainfall aberration (Table 2).

Table 2 Contingency crop plan for different abnormalities

Rainfall abnormality	Contingency plan and midterm correction
1. Delayed onset of rainfall	
a) Delay exceeding-4 weeks	Alternate crops of short duration to be sown
Delay in South west monsoon Normal - June Delay - July Delay - August	 Groundnut Ragi / pearl millet Sama (little millet) / Cowpea
Delay in North east monsoon Normal - October Delay - Early November Delay - Late November	 Cotton / Sorghum Sunflower / Pearl millet / Ragi Coriander / Bengalgram
b) Delay of 1 to 2 weeks	Alternate varieties of short duration of same crop Eg. Sorghum Co 19 (150 days) Co 25 (110 days), Red gram local (180 days) Co 5 (130 days)
2. Early withdrawal of rainfall	Antitranspirant spray, harvesting for fodder (millets), harvesting at physiological maturity
3. Intermediary dry spell	
a. Immediately after sowing	Gap filling with subsequent rains if stand reduction is less than 20%. Re-sowing if stand reduction is more than 20%, mulching between crop rows. Stirring soil surface to create dust mulch to reduce evaporation
b. At vegetative phase	Mulching,antitranspirant spray, spraying potassium chloride, thinning of 33-50 % population
c. At flowering	Antitranspirant spray, harvesting for fodder and ratooning with subsequent rains in millets (e.g sorghum)
d. At ripening	Antitranspirant spray, harvesting for fodder, harvesting at physiological maturity

Crops have to be selected with suitable crop duration to coincide with the length of the growing season. Generally short duration pulses like greengram, blackgram and cowpea may suit the situation. However if the monsoon turns to be extraordinarily good, opportunity is lost if only short duration crops are sown. Farmers with economic strength and motivation for high profits with some amount of risk can go for crops of long duration. The long duration crops with flexibility or elasticity in yield are more suitable. For example, pearlmillet, and sorghum can be ratooned if monsoon extends. Sunflower can be introduced for higher profits with certain amount of risk. Crops like sorghum, pearlmillet, can be grown for grain if monsoon extends and if not, fodder can be obtained.

Contingency crop planning suggested by IGFRI- Jhansi for Banda District of U.P.

Abb. Type*	Gen. Precaution	*Kharif*		*Rabi*		*Zaid*	
		Red Soil	Black Soil	Red Soil	Black Soil	Red Soil	Black Soil
1.	-	Dry sowing of jowar/bajra, paddy upland, rest normal kharif crop late nursery (paddy)	Dry sowing of jowar/bajra, rest normal crop, upland paddy, late nursery (paddy)	Normal *rabi* crops	Normal rabi crops	-	-
2.	Bunding for moisture conservation, summer ploughing	Sowing of urd, mung, til jowar/ bajra	Sowing of jowar/bajra urd barley, gram	Normal *rabi* crop emphasis on barley, gram, mustard, pea	Normal rabi crop, emphasis on pea, mustard, lentil	Maize	Mung
3.	-	Mulching after 1 week drought normal kharif	Mulching after 10 days drought normal kharif	Normal *rabi*	Normal rabi	Maize	Mung
4.	-	Save part crop by irrigation, rest use for hay/silage	Save part crop by irrigation, rest use for hay/silage	Timely/early sowing of gram, pea, wheat, barley	Timely sowing of lentil, gram, pea, barley, wheat	Maize,	Mung
5.	Bunding for moisture conservation, summer ploughing, reduce field size to a max. 0.4 ha	Mix crop of jowar/bajra + pigeonpea, sole crop of til, arhar, upland paddy	Mix crop of jowar/ bajra+urd+ mung+ pigeonpea, sole crop of til, arhar, upland paddy	Barley, gram, pea, mustard + linseed under mix cropping, sole cropping of Kathia wheat and above crops	Mixed crop of Kathia + gram + linseed, sole crop of lentil, Gram	-	-

6.	Arrange drainage in field. Reduce field size to a max. of 0.4 ha	Paddy in field, pigeonpea on bunds, jowar/ bajra, urd, mung	Paddy in field and pigeonpea on bund jowar/ bajra, urd	Normal *rabi* crops	Normal *rabi* crops	Maize, mung, vegetables, flowers	Mung, vegetables, flowers
7.	-	Normal *kharif* paddy	Normal *kharif* paddy	Tall Indian wheat, barley, Kathia wheat, gram, pea, terameera, mustard, safflower	Tall India wheat, Kathia wheat, barley, gram, lentil, Terameera, Mustard, Safflower	-	-
8.	Arrange drainage and grassed waterways	Normal	Normal	Wheat, gram, pea	Wheat, gram, massor	Maize	Mung
9.	-	Normal	Normal	Late sowing, increased seed rate of wheat, barley, under rainfed condition, Taramira	Late sowing with increased seed rate of wheat, barley, Taramira, Safflower	Maize	Mung
10.	-	Normal	Normal	Water crop to save shriveling of grain	Water crop to save grain shriveling	Maize	Mung

*Aberration type-1. Delayed monsoon by 15 days; 2. Delayed monsoon by 1 month; 3. Timely monsoon followed by long dry spell; 4. Early cessation of monsoon; 5. Drought like situation (rainfall <81%); 6. Excessive rainfall; 7. No winter rains; 8. Excessive winter rains; 9. High temperature in October-November; 10. Early temperature rise in February-March.

ABOUT THE AUTHOR

Dr. Aniket Kalhapure is presently working as Assistant Professor of Agronomy at Banda University of Agriculture & Technology, Banda (U.P.). He has completed B.Sc. (Agri.) from Mahatma Phule Krishi Vidyapeeth, Rahuri; M.Sc. (Agri.) in Agronomy discipline from Marathwada Agricultural University, Parbhani and Ph.D. (Agronomy) from GB Pant University of Agriculture & Technology, Pantnagar. He has fourteen years active experience in research, teaching, farm management and implementing the extension activities in the field of Agriculture. His more than 25 research papers have been published in various national and internationally recognized journals. He also has the credit of several technical papers, popular articles, book chapters, text books, other extension literature and radio talks in his name and contributed to the recommendation of various agro-technologies for the welfare of farmers. He is rewarded with the fellowships of South Asia Foundation and SERB- Department of Science & Technology, Govt. of India.

ISBN 9 788195 894918