ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY

By

Dr.T.Yellamanda Reddy

and

Dr. G. Prabhakara Reddy

Department of Agronomy

ACHARYA N. G. RANGA AGRICULTURAL UNIVERSITY

AGRO 102 (New) Dryland Farming and Watershed Management

Lecture Notes

Prepared by

Dr.T.Yellamanda Reddy

Dean (Agril.)

and

Dr. G. Prabhakara Reddy

Associate Professor

Department of Agronomy

Preface

This book is meant for undergraduate level students of agriculture for dryland farming and watershed management course. It will be useful for post graduate students of agronomy and soil science. This book is also useful for officials of agriculture and horticulture departments, who deal with the implementation of dryland and watershed technology at village level.

This book covers all the topics related to dryland farming and watershed management in a simple form. The topics were dealt along with tables, formulae, figures and illustrations for easy understanding of the subject.

The suggestions from the readers are welcome to improve the text book.

Authors

CONTENTS

Syllabus

Dryland Farming and Watershed Management **2(1+1)**

Theory

Dryland farming – introduction and definition. Management of land and water, the basic resources. Dry climates and their classification. Activities of research centres of dryland agriculture. Problems of crop production in dryland agriculture. Existing pattern of land use in low rainfall areas.. Rainfall patterns in dry regions. Drought-occurrence, types and management strategies for drought. Soil erosion- types, factors affecting erosion, agronomic soil conservation measures. Fertilizer use in dryland agriculture, inorganic, organic and biofertilizers. Efficient crops and varieties, cropping systems, normal and contingency crop planning under aberrant weather conditions. Evapotranspiration – measures to reduce evaporation and transpiration. Watershed management – objectives and approaches, steps in watershed planning. Land use capability and classification. Soil and water conservation measures in watershed areas. Water harvesting and life saving irrigation. Problems and prospects under watersheds. Alternate land use systems

Practicals

1. Allotment of plots and preparation of seed bed
2. Fertilizer application and sowing
3. Rainfall analysis and interpretation
4. Study of dry farming implements
5. Study of agronomic measures of soil and moisture conservation
6. Study of mulches and antitranspirants
7. Demonstration of land treatments for moisture conservation
8. Visit to watershed areas
9. Study of drought effects on crops
10. Study of efficiency of land treatments for moisture conservation
11. Collection of biometric data on crop and its interpretation
12. Study of soil erosion problems in the field
13. Collection of data on temperature and evaporation

14, 15 & 16. Harvesting, post harvesting operations and recording of yield.

Lecture Outlines

Lecture No. 1 Dryland farming - introduction and definition - dimensions of the problem -area and production from drylands in India and Andhra Pradesh

Lecture No. 2 Dry climates and their classifications - moisture index - semi-arid and arid climates -objectives and activities of CRIDA - its main and coordinating centers.

Lecture No. 3 Problems of crop production in drylands - climate - rainfall pattern -distribution - variabilities in rainfall - short rainy season - high intensity rainfall - soil characteristics - soil fertility status - soil moisture storage and retention capacity - heavy weed infestation and economic conditions of the farmer - outlines of management of land and water, the basic resources.

Lecture No. 4 Existing pattern of land use in low rainfall areas - drought - definition - types and occurrence of drought - management strategies for drought - mid season correction - soil mulch - adjusting plant population to limited moisture supply - increasing inter row distance - thinning plant population.

Lecture No. 5 Tillage for dryland crops - deep ploughing - setline cultivation - year round tillage - minimum tillage and zero tillage - seeding practices - soil crusts and their effect on crop and soils - avoiding crust problems.

Lecture No. 6 Soil erosion - definition - losses due to erosion - types of soil erosion – nature and extent of wind and water erosion - factors affecting erosion -universal soil loss equation

Lecture No. 7 Agronomic measures of soil conservation -contour cultivation - strip cropping - cover cropping.

Lecture No. 8 Fertilizer use in dry lands - use of organic manures - introduction of legumes in crop rotation - organic recycling and bio-fertilizer use in dry land agriculture- time and method of fertilizer application - fertilizer use in relation to moisture conservation.

Lecture No. 9. Cropping systems in drylands - inter cropping advantages - efficient inter cropping systems in different dry farming regions of Andhra Pradesh - choice of crops and varieties.

Lecture No. 10. Contingent crop planning for aberrant weather conditions in red and black soils under normal monsoon - delayed onset of monsoon - normal monsoon followed by long dry spells and early cessation of monsoon.

Lecture No. 11. Evapotranspiration - measures to reduce evapotranspiration – weeding - use of mulches - chemicals, windbreaks, shelterbelts.

Lecture No. 12. Watershed management - definition of watershed - area of operation of watersheds in A.P. Objectives and approaches of watershed management

Lecture No. 13. Components of watershed development programme – land use capability and classification.

Lecture No. 14. Soil and water conservation measures in watershed areas - Agronomic measures - bund former - bunding, dead furrow - ridge and furrow system -interplot water harvesting - mechanical measures - gully control, level bench terraces - contour terracing - graded bunds

Lecture No. 15. Water harvesting structures - farm ponds, check dams - percolation tank - life saving irrigation - problems and prospects under watersheds.

Lecture No. 16 Alternate land use systems - advantages - agro-forestry systems - alley cropping - silvi - pastoral systems - agri - silvi - pastoral system - agri-horticultural system - silvi horticultural system - multi purpose forest tree production system.

Lecture No. 1 Dryland farming-introduction and definition and importance

1.1 Introduction

Agriculture is the single largest livelihood sources in India with nearly two thirds of people depend on it. Rainfed agriculture is as old as agriculture it self. Growing of crops entirely under rainfed conditions is known as dryland agriculture. Depending on the amount of rainfall received, dryland agriculture can be grouped into three categories:

1.2 Definitions

a) 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 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.

Dryland vs. rainfed farming

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

1.3 Importance of Dry farming in Indian Agriculture

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

2. Dryland Agriculture plays a distinct role in Indian Agriculture occupying 60% of cultivated area and supports 40% of human population and 60 % livestock population.

3. 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.

4. By the end of the 20^{th} century the contribution of drylands will have to be 60 per cent if India is to provide adequate food to 1000 million people. Hence tremendous efforts both in the development and research fronts are essential to achieve this target.

5. 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.

6. At present, 3 ha of dryland crop produce cereal grain equivalent to that produced in one ha irrigated crop. With limited scope for increasing the area under plough, only option left is to increase the productivity with the modern technology and inputs, since the per capita land availability which was 0.28 ha in 1990 is expected to decline 0.19 ha in 2010.

7. 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.

8. 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.

1.4 Dimensions of the problem:

Majority of the districts in India are dry farming districts and covers 60 per cent of the total 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. In south India the Deccan plateau which is rain shadow area consisting of parts of Karnataka, (Bellary, Raichur, Kolar, Tumkur, Dharwad, Belgam, Gulberga) and Maharastra (Sholapur, Parbani, Puna, Aurangabad). The dry farming areas in Andhra Pradesh are found in Kurnool, Anantapur, Kadapa, Mahaboobnagar, Chittoor, and Nalgonda districts.

a) The area under dryland agriculture is more in India (60 per cent of total cultivable area)

b) Areas of low rainfall (below 750 mm) constitute more than 30 per cent of total geographical area

c) About 84 districts in India fall in the category of low rainfall area

d) Providing irrigation to all the drylands is expensive and takes long time

e) Even after providing all the irrigation potential in India 55 per cent area remains as rainfed

1.5 Area under dry lands

Globally the area under drylands is about 6150 m.ha. In India out of the total cultivated area of 143 m.ha the area under drylands is about 85 m.ha, which comes to 60% . It is estimated that even after creating entire irrigation potential for irrigation about 55% of total cultivated area remain as rainfed. Except in the states of Punjab, Haryana and Pondichery the percentage of area under drylands is high in all other states. In Andhra Pradesh the area under drylands is about 6.576 m.ha (60 %).

Dry land area in different regions of India

Region	States	Per cent 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

Lecture No. 2 Dry climates and their classification- objectives and activities of CRIDA

2.1 Indices of Aridity

Aridity refers to a condition of deficiency of water due to either insufficient precipitation or excess water loss over supply. The term "arid" is derived from a Latin word, "arere" which means 'dry'.

Assessment of the degree of aridity of a place is necessary to serve as a base for the application of technology, for the interpretation of resource assessment and for transfer of technology. It also useful to analyse the climatic resources and to identify specific climatic constraints for planning agricultural development.

The degree of aridity can be assessed from climatic parameters and plant criteria. More than 50 classifications of agro-climate was made by many scientists. Some of the important classifications are discussed below.

2.2 Classification of dry climates

2.2.1 Thornthwaite and Mather (1955)

They have taken the Moisture Index (I_m) as the criteria for classification of dry climates

$$I_m = [(P-PE)/PE]\ 100$$

where, P = Precipitation, PE = Potential Evapo-transpiration

I_m Quantity	Climate classification
100 and above	Per humid
20 to 100	Humid
0 to 20	Moist sub humid
-33.3 to 0	Dry sub humid
-66.7 to -33.3	Semi arid
-100 to -66.7	Arid

2.2.2 Troll (1965)

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

Humid months	Climate classification
12.0 to 9.5	Tropical rainforest
9.5 to 7.0	Humid Savannah
7.0 to 4.5	Dry Savannah (Wet – dry SAT)
4.5 to 2.0	Thorn Savannah (Dry SAT)
2.0 to 1.0	Semi desert (Arid)
1.0 to 0.0	Desert (Arid)

2.2.3. Papadakis (1961)

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

$$H = [P + W] / E$$

where,

P = Monthly precipitation

E = Monthly PET

W = Water stored from previous rainfall

H value	Climate
Less than 0.25	Arid
0.25 to 0.50	Dry
0.50 to 0.75	Intermediate
0.75 to 1.00	Intermediate humid
1.00 to 2.00	Humid
More than 2.00	Wet

2.2.4 Hargreaves (1971)

Moisture Availability Index (MAI) is used for the classification. It is the ratio of dependable precipitation to potential evapotranspiration. It is a measure of adequacy of precipitation in supplying crop water demand.

$$\text{MAI} = \frac{\text{Depandable precipitation (75\% probable rainfall)}}{\text{Potential evapo transpiration}}$$

MAI	Climate classification
0.0 to 0.33 during all months	Very arid
More than 0.34 for 1-2 months	Arid
More than 0.34 for 3-4 consecutive months	Semi arid

2.2.5 Steiner *et al.*, (1988)

After careful consideration of several definitions, Steiner et al. (1988) consider aridity index concept of the United Nations Conference on Desertification based on the balance between precipitation (P) and evapotranspiration (ETP) to be appropriate for wide scale adoption. According to this definition the areas with P/ETP ratio between 0.03 and 0.20 are arid and areas with the ratio between 0.2 and 0.5 are semi-arid.

2.2.6 FAO classification

This classification is based on 'growing period concept' of the FAO. Areas having a growing period between 1 and 74 days are classified as arid and those with a growing period between 75 and 119 days are semiarid. (**Growing period** is the number of days during a year when precipitation exceeds half the potential evapotranspiration, plus a period to use an assumed 100 mm of water from excess precipitation (or less, if not available) stored in the soil profile).

2.2.7 ICAR classification of agro- climatic zones

ICAR while establishing the dryland centers in different agro -climatic zones of the country in 1970, used the simple formula of Thornthwaite (1955) for estimating the moisture index.

$$\text{Moisture Index} = 100\ [(P-PE)/PE]$$

Thornthwaite and Mather (1955) gave only six classifications while the ICAR (Krishnan and Mukhtar Singh (1968) had eight moisture indices with eight moisture belts indicating eight zones in India. The scale adopted in defining climatic zones in terms of moisture indices are

Zone	**Moisture Index**	**Moisture belt**
1	< -80	Extremely dry
2	-60 to -80	Semi dry
3	-40 to -60	Dry
4	-20 to -40	Slightly dry
5	0 to -20	Slightly moist
6	0 to +50	Moist
7	+50 to +100	Wet
8	> +100	Extremely wet

All India coordinated Research Project on dryland Agriculture of ICAR has divided climate into three types based on moisture deficit index (MDI)

$$\text{MDI} = [(P-PET)/PET]$$

where, PET is estimated based on temperature as PET= 2T where T is average temperature in °C .

Climate	**MDI**
Sub humid	0 to 33.3
Semi arid	- 33.3 to 66.6
Arid	> - 66.6

2.3Arid and semi arid zones

a) Arid regions: The arid zones will have moisture index between –66.7 to –100. Precipitation is less than potential evaporation for the grater part of the year. Arable crop production is not possible without irrigation. Growing period is between 1 to 74 days.

b) Semi arid zones: They have moisture index values between –33.3 to –66.7. Crop production is possibly by adopting moisture conservation practices. Growing period is between 75 to 119 days.

A semi arid climate is essentially a mixed climate in which a fairly moist or rainy season alternates with a completely dry season. Hence, the climate is described as alternating wet and dry climate. Rainfall occurs during 2 to 7 months of the year. When number of wet months is 2.0 to 4.5, it is described as dry SAT and when rainy months ranges from 4.5 to 7.0 it is called as wet SAT. Rainfall quantity ranges from 400 to 750 mm per year, with a variability of 20 to 30%. But, the onset, closure and duration of rainy season exhibits wide variability between years. Distribution of rainfall within the season also exhibits wide fluctuations between years. Mean annual temperature is more than 18 °C.

Arid and Semi arid regions of India

Total area under arid and semiarid regions in India extends over 135.8 million hectares

Climate	Area (m ha)	Regions
Arid Tropics	31.7	Rajasthan, Gujarat, Punjab, Haryana, Parts of Karnataka and Andhra
Arid Temperate	7.0	Jammu and Kashmir
Semiarid Tropics	95.7	Maharastra, Karnataka, Andhra, Rajasthan, Tamilnadu, Gujarat, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh
Semiarid Temperate	1.4	Jammu and Kashmir

Temperature in arid and semiarid temperate region is maximum at 32°C in July and minimum at -14°C in January – February. Temperature in arid and semiarid tropics is maximum at 40-42°C in May and minimum varies from 3-5°C in Punjab and Haryana and 18-24°C in Tamilnadu.

Distribution of arid and Semi arid regions of India

State	Arid		Semiarid	
	Area (Sq km)	Per cent to total area in India	Area (Sq km)	Per cent to total area in India
A. Tropics				
Rajasthan	196150	61	121020	13
Gujarat	62180	20	90520	9
Punjab	14510	5	31770	3
Haryana	12840	4	26880	3
Uttar Pradesh	-	-	64230	7
Madhya Pradesh	-	-	59470	6
Maharastra	1290	0.4	189580	19
Karnataka	8570	3	139360	15
Andhra Pradesh	21550	7	138670	15
Tamilnadu	-	-	95250	10
All India	317090	-	956750	-
B. Temperate				
Jammu & Kashmir	70300	-	13780	-

The words “Arid” and “Semiarid” must be understood differentially from dry farming. All the dry farming areas are located in arid and semi arid regions only. But not all the arid and semiarid regions come under dry farming areas. When irrigation facilities are available, irrigated farming is practiced extensively in arid and semiarid regions also. Eg. Punjab, Haryana.

2.3 Progress of dryland Agricultural Research in India

Though dryland farming is as old as agriculture, the systematic research work was started only from 1923 with the start of Research Centre at Manjri near Pune, in

Bombay province by V.A. Tamhane. Later Imperial Council of Agricultural Research (presently Indian Council Agricultural Research) started research schemes at Bombay, Madras, Hyderabad and Punjab provinces. Around 1933, systematic work was started on different aspects of crop production under rainfed conditions. The findings of the period were related to rainfall analysis. It was found that rainfall was not only scarce but also erratic. The dry spells during the crop period ranged from 20 to 55 days. Therefore, the emphasis on research was given to conserve soil moisture and to reduce evaporation. Based on the studies conducted between 1933 and 1943, package was developed for better crop production under rainfed conditions. The important practices are:

1. Formation of contour bunds.
2. Repeated harrowing in black soils to conserve moisture.
3. Addition of farm yard manure to maintain the soil fertility.
4. Wider spacing for crops grown on residual moisture.

The package of practices were named after the province from which they were developed as Bombay dry farming practices, Madras dry farming practices, Hyderabad dry farming practices and Punjab dry farming practices. The adoption of these practices was low due to marginal increase in yield. Government programmes mainly concentrated on contour bunding which provided employment during drought periods. During 1954, the soil conservation training and demonstration centres were established by Indian Council of Agriculture Research at eight locations. These centres concentrated on soil conservation techniques and training of officers on soil conservation, while crop production received low importance. During 1970, ICAR started All India Coordinated Research Project on Dryland Agriculture at 23 locations spread all over India. Under the scheme, an integrated approach was adopted to solve the problems of dryland agriculture, by including the disciplines of agronomy, soil science, plant breeding and agricultural engineering. The important practices developed under the scheme are contingent cropping, efficient crops and cropping systems, water harvesting and supplemental irrigation, drought resistant varieties, fertilizer recommendation and agricultural implements. Watershed approach was fallowed to popularise these technology by including soil conservation practices with improved dryland practices, alternate crops and other ancillary enterprises. In 1983, 47 model watersheds were developed. Based on the success of this approach in increasing the productivity of drylands, the national watershed development programme for dryland agriculture was started through out the country.

The chronology of events in dryland agricultural research in India is as follows.

1920	Scarcity tract development given importance by the Royal Commission on Agriculture
1923	Establishing Dryland Research Station at Manjri (Pune) by Tamhane
1933	Research Stations established at Bijapur and Solapur
1934	Research Stations established at Hagari and Raichur
1935	Research Station established at Rohtak (Punjab)
1942	Bombay Land Development act passed
1944	Monograph on dry farming in India by N.V. Kanitkar (Bombay, Hyderabad, Madras Dry Farming Practices)
1953	Establishing Central Soil Conservation Board
1954	Establishing Central Soil Conservation Centres
1970	Research Centres established under AICRPDA in 23 locations
1972	Establishment of ICRISAT
1976	Establishment of Dryland Operational Research Projects
1983	Starting of 47 model watersheds under ICAR
1984	Initiation of World Bank assisted Watershed Development Programmes in four states. Establishing Dryland Development Board in Karnataka
1985	Birth of Central Research Institute for Dryland Agriculture at Hyderabad
1986	Launching of NWDPRA programmes by Government of India in 15 states.

Recognizing the importance of rainfed agriculture, the ICAR gave a new impetus by launching the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) in 1970, based at Hyderabad with 23 cooperating centres spread across the country. Pooling of expertise and leveraging the strengths of AICRPDA net work eventually resulted in the establishment of Central Research Institute for Dryland Agriculture (CRIDA) at Hyderabad, on April 12, 1985 to provide leadership in basic strategic research in dryland agriculture while continuing research on location specific ORP' s at AICRPDA centres. At present the AICRPDA centres are located at 25 places.

Mandate/objectives of CRIDA

a) To conduct basic and applied researches that will contribute to the development strategies for sustainable faming systems in the rainfed areas.

b) To conduct basic and applied researches that will contribute to the development strategies for sustainable faming systems in the rainfed areas.

c) To act as a repository of information on rainfed agriculture in the country

d) To provide leadership and co ordinate network with state agricultural universities for generating location specific technologies for rainfed areas

e) To act as a centre for training in research methodologies in the fields basic to management of rainfed farming systems

f) To collaborate with relevant national and international agencies in achieving the above objectives , and

g) To provide consultancy

Lecture No.3 Problems of crop production in drylands

3.1 Problems or constraints for crop production in dry farming regions

Most of the cropping in the arid and semi arid regions continues to be under rainfed conditions. A majority of the farmers are small farmers with meagre resources. The poor resource base permits only low input subsistence farming with low and unstable crop yields. The low productivity of agriculture in dry farming regions is due to the cumulative effect of many constraints for crop production. The constraints can be broadly grouped in to

a) Climatic constraints,

b) Soil related constraints,

c) Traditional cultivation practices

d) Heavy weed problem

e) Lack of suitable varieties and

f) Socio economic constraints.

3.1.1 Climatic constraints

A) Rainfall characteristics: Among the different climatic parameters rainfall is an important factor influencing the crop production in dry regions

(i) **Variable rainfall:** Rain fall varies both in time and space dimension. Annual rainfall varies greatly from year to year and naturally its coefficient of variation is very high. Generally, higher the rainfall less is the coefficient of variation. In other words, crop failures due to uncertain rains are more frequent in regions with lesser rainfall. The average annual rainfall of India is 1192 mm where as in Andhra Pradesh it is 890 mm. Based on the average annual rainfall, the India can be divided into four zones. More than one third of total geographical area in India receive rainfall less than 750 mm (Table.3.1)

Table 3.1 Classification of India into different zones based on rainfall

Zone	Average annual rainfall (mm)	Per cent of geographical area
Zone I (very low rainfall area)	< 350	13
Zone II (low rainfall area)	350 to 750	22
Zone III (Medium rainfall area)	750 to 1125	36
Zone IV (High rainfall area)	> 1125	29

(ii) Intensity and distribution: In general, more than 50 per cent 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. Distribution of rainfall during the crop growing season is more important than total rainfall in dryland agriculture.

iii) Aberrations or variations in monsoon behaviour

(a) Late onset of monsoon: If the onset of monsoon is delayed, crops/varieties recommended to the region cannot be sown in time. Delayed sowing lead to uneconomical crop yields.

(b)Early withdrawal of monsoon: 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.

(c) Prolonged dry spells: Breaks of monsoon for 7-10 days may not be a serious concern. Breaks of more than 15 days duration especially at critical stages for soil moisture stress leads to reduction in yield. Drought due to break in monsoon may adversely affect the crops in shallow soils than in deep soils.

B) High atmospheric temperature: Because of high atmospheric temperature the atmospheric demand for moisture increases causing high evapotranspiration losses resulting in moisture stress.

C) Low relative humidity: Low relative humidity results in high ET losses causing moisture stress whenever moisture is limiting.

D) Hot dry winds: Hot dry winds causes decicassion of leaves resulting in moisture stress. High turbulent winds especially during summer months cause soil erosion resulting in dust storms and loss of fertile soil.

E) High atmospheric water demand: Due to high atmospheric water demand the potential evapotranspiration (PET) exceed the precipitation during most part of the year.

3.1.2 Soil Constraints

The different soil groups encountered in dryland areas are black soils, red soils and alluvial soils. The constraints for crop production are different in different soil groups. The predominant soil group is alluvial where the problems for crop production are not so acute as in red and black soils .The different soil constraints for crop production are

a) 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.

b) 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.

c) 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.

d) 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.

e) 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.

f) 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.

3.1.3 Cultivation practices

The existing management practices adopted by the farmers are evolved based on long term experience by the farmers.

The traditional management practices are

- Ploughing along the slope
- Broadcasting seeds/ sowing behind the country plough leading to poor as well as uneven plant stand
- Monsoon sowing
- Choice of crops based on rainfall
- Application FYM in limited quantity
- Hand weeding
- Mixed cropping
- Use of conventional system of harvesting
- Traditional storage system

3.1.4 Heavy weed infestation: This is the most serious problem in dryland areas. Unfortunately the environment congenial for crop growth is also congenial for weed growth. Weed seeds germinate earlier than crop seeds and try to suppress the crop growth. The weed problem is high in rainfed areas because of continuous rains and acute shortage of labour. The weed suppression in the early stage of crop growth is required to reduce the decrease in crop yields.

3.1.5 Lack of suitable varieties: Most of the crop varieties available for cultivation in dry lands are meant for irrigated agriculture. There are no any special varieties exclusively meant for dryland areas. Hence still more efforts are required to develop varieties in different crops exclusively meant for dryland agriculture.

3.1.6 Socio-economic constraints: The economic condition of the dryland farmers is very poor because

a) Less access to inputs

b) Non availability of credit in time

c) The risk bearing capacity of dryland farmer is very low

Hence the dryland farmers resort to low input agriculture which results in poor yields.

3.2 Management of Natural Resources

The national resources that are to be managed on sustainable basis are soil, water, vegetation and climate .India is blessed with vast natural resources of land, water, vegetation and climate but with poor quality of life. They can be managed by

a) Characterization and development of sustainable land use plans for each agro ecological region in the country

b) Soil and moisture conservation

c) Integrated soil fertility management

d) Interbasin transfer of surface flow which is otherwise going as waste for seas and oceans

e) Creation of live storage of water by constructing reservoirs

f) Integrated water management of surface and ground water sources

g) On farm irrigation water management to enhance water use efficiency

Lecture No. 4 Drought and drought management strategies

4.1 Introduction

Low rainfall or failure of monsoon rain is a recurring feature in India. This has been responsible for droughts and famines. The word drought generally denotes scarcity of water in a region. Though, aridity and drought are due to insufficient water, aridity is a permanent climatic feature and is the culmination of a number of long term processes. However, drought is a temporary condition that occurs for a short period due to deficient precipitation for vegetation, river flow, water supply and human consumption. Drought is due to anomaly in atmospheric circulation.

Aridity Vs. Drought

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

4.2 Definition of drought

There is no universally accepted definition for drought.

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 evapo-transpiration 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.

4.3 Classification of drought

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

4.3.1 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.

4.3.2 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 evapo-transpiration losses.

4.3.3 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.

4.3.4. 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. For 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.

4.4 Important causes for agricultural drought are

- Inadequate precipitation
- Erratic distribution
- Long dry spells in the monsoon
- Late onset of monsoon
- Early withdrawal of monsoon
- Lack of proper soil and crop management

4.5 Periodicity of drought

The Indian Meteorological Department examined the incidence of drought for the period from 1871 to 1967, utilizing the monthly rainfall of 306 stations in the country. It was seen that during 1877, 1899, 1918 and 1972 more than 40 per cent of the total area experienced drought. General observation on the periodicity of drought in respect of different meteorological sub divisions of India is given below.

Meteorological sub divisions	Period of recurrence of drought
Assam	Very rare, once in 15 years
West Bengal, MP, Konkan, Coastal AP, Kerala, Bihar, Orissa	Once in 5 years
South interior Karnataka, Eastern UP, Gujarat, Vidharbha, Rajasthan, Western UP, TN, Kashmir, Rayalaseema and Telangana	Once in 3 years
Western Rajasthan	Once in 2.5 years

4.6 Effect of drought on crop production

a) 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.

b) 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).

c) Respiration: Increase with mild drought but more serve drought lowers water content and respiration.

d) 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.

e) Metabolic reaction: All most all metabolic reactions are affected by water deficits.

f) 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.

g) Nutrition: The fixation, uptake and assimilation of nitrogen is affected. Since dry matter production is considerably reduced the uptake of NPK is reduced.

h) 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.

i) 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.

j) 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.

4.7 Crop Adaptations

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.

Crops survive and grow under moisture stress conditions mainly by two ways: (i) escaping drought and (ii) drought resistance (Fig. 4.1)

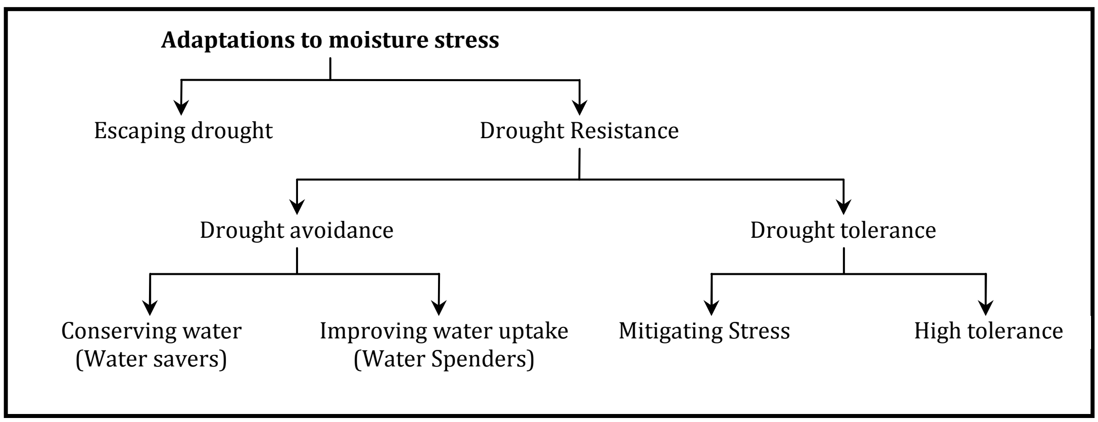


Fig. 4.1 Flow chart showing different mechanisms for overcoming moisutre stess

4.7.1 Escaping Drought

Evading the period of drought is the simplest means of adaptation of plants to dry conditions. Many desert plants, the so called ephemerals, germinate at the beginning of the rainy season and have an extremely short life period (5 to 6 weeks) which is confined to the rainy period. These plants have no mechanism for overcoming moisture stress and are, therefore, not drought resistant. Germination inhibitors serve as safety mechanism.

In cultivated crops, the ability of a cultivar to mature before the soil dries is the main adaptation to growth in dry regions. However, only very few crops have such a short growing season to be called as ephemerals. Certain varieties of pearl millet mature within 60 days after sowing. Short duration pulses like cowpea, greengram, blackgram can be included in this category. In addition to earliness, they need drought resistance because there may be dry spells within the crop period of 60 days. The disadvantage about breeding early varieties is that yield is reduced with reduction in duration.

4.7.2 Drought Resistance

Plants can adopt to drought either by avoiding stress or by tolerating stress due to different mechanisms. These mechanisms provide drought resistance.

4.7.3 Avoiding Stress

Stress avoidance is the ability to maintain a favourable water balance, and turgidity even when exposed to drought conditions, thereby avoiding stress and its consequences. A favourable water balance under drought conditions can be achieved either by: (i) conserving water by restricting transpiration before or as soon as stress is experienced; or (ii) accelerating water uptake sufficiently so as to replenish the lost water.

4.8 Strategies for drought management

The different strategies for drought management are discussed under the following heads.

4.8.1 Adjusting the plant population: The plant population should be lesser in dryland conditions than under irrigated conditions. The rectangular type of planting pattern should always be followed under dryland conditions. Under dryland conditions whenever moisture stress occurs due to prolonged dry spells, under limited moisture supply the adjustment of plant population can be done by

a) Increasing the inter row distance: By adjusting more number of plants within the row and increasing the distance between the rows reduces the competition during any part of the growing period of the crop. Hence it is more suitable for limited moisture supply conditions.

b) Increasing the intra row distance: Here the distance between plants is increased by which plants grow luxuriantly from the beginning. There will be competition for moisture during the reproductive period of the crop. Hence it is less advantageous as compared to above under limited moisture supply.

4.8.2 Mid season corrections: The contingent management practices done in the standing crop to overcome the unfavourable soil moisture conditions due to prolonged dry spells are known as mid season conditions.

a) Thinning: This ca be done by removing every alternate row or every third row which will save the crop from failure by reducing the competition

b) Spraying: In crops like groundnut, castor, redgram, etc., during prolonged dry spells the crop can saved by spraying water at weekly intervals or 2 per cent urea at week to 10 days interval.

c) Ratooning: In crops like sorghum and bajra, ratooning can practiced as mid season correction measure after break of dry spell.

4.8.3 Mulching: It is a practice of spreading any covering material on soil surface to reduce evaporation losses. The mulches will prolong the moisture availability in the soil and save the crop during drought conditions.

4.8.4 Weed control: Weeds compete with crop for different growth resources ore seriously under dryland conditions. The water requirement of most of the weeds is more than the crop plants. Hence they compete more for soil moisture. Therefore the weed control especially during early stages of crop growth reduce the impact of dry spell by soil moisture conservation.

4.8.5 Water harvesting and life saving irrigation: The collection of run off water during peak periods of rainfall and storing in different structures is known as water harvesting. The stored water can be used for giving the life saving irrigation during prolonged dry spells.

Lecture No. 5 Tillage and seeding practices in drylands

5.1 Tillage

The mechanical manipulation of soil with tools and implements for obtaining conditions ideal for seed germination, seedling establishment and growth of crops is known as tillage. Tillage may be described as the practice of modifying the state of the soil in order to provide conditions favourable to crop growth, (Cuplin, 1986). The objectives of tillage in drylands are

(1) Develop desired soil structure for a seed bed which allows rapid infiltration and good retention of rainfall.

(2) Minimize soil erosion by following practices such as contour tillage, tillage across the slope etc.

(3) Control weeds and remove unwanted crop plants.

(4) Manage crop residues

(5) Obtain specific land configurations for *in*- situ moisture conservation, drainage, planting etc.

(6) Incorporate and mix manures, fertilizers, pesticides or soil amendments into the soil.

(7) Accomplish segregation by moving soil from one layer to another, removal of rocks or root harvesting.

Hence, attention must be paid to the depth of tillage, time of tillage, direction of tillage and intensity of tillage.

5.1.1 Depth of tillage – It depends on soil type, crop and time of tillage

a) Deep tillage: of 25-30 cm is beneficial for deep heavy clay soils to improve permeability and to close cracks formed while drying. In soils with hard pans, deep tillage once in 2-3 years with chisel plough up to 35-45 cm depth at 60-120 cm interval will increase effective depth for rooting and moisture storage. Deep tillage is preferable for cotton, redgram and other deep rooted crops. It is not to be recommended for shallow, gravelly, light textured soils.

b) Medium deep tillage: of 15-20 cm depth is generally sufficient for most soils and crops. It is recommended for medium deep soils, shallow rooted crops, soils with pan free horizon and for stubble incorporation.

c) Shallow tillage: up to 10 cm is followed in light textured soils, and shallow soils and in soils highly susceptible to erosion. In soils prone for surface crusting, shallow surface stirring or shallow harrowing is useful.

As depth of tillage increases, soil moisture storage from rainfall also increases from about 7-8 % with shallow tillage to 9-10% with medium deep tillage and 11-12% with deep tillage.

5.1.2 Time of tillage

Early completion of tillage is often helpful to enable sowing immediately after rainfall and before the soil dries up. Summer tillage or off-season tillage done with pre season rainfall causes more conservation of moisture and also enables early and timely sowing. It is particularly useful for pre-monsoon sowing.

a) Year round tillage: Here the tillage operations are carried out throughout the year in dry farming areas. The tillage operations are started immediately after the receipt of summer showers and continued till sowing of the crops. After harvest of the crop, by taking the advantage of the residual soil moisture the soil is ploughed once or twice to retain the soil moisture in the lower layers. The advantages of year round tillage are reduced weed growth, better tilth, adequate soil moisture, and timely sowing.

5.1.3 Direction of tillage

For moisture conservation, ploughing across the slope or along the contour is very effective. Plough furrows check the velocity of runoff, promote more infiltration and improve soil moisture storage.

5.1.4 Intensity of tillage

It refers to the number of times tillage is done. Frequent ploughing in shallow light textured soils will pulverize the soils into fine dust and increase the susceptibility to erosion. In heavy soils, leaving the land in a rough and cloddy stage prior to sowing is useful for more depression storage.

The concept of minimal tillage is also practiced in dry lands. Here tillage is confined to seeding zone only and the inter-space is not tilled. It not only saves time, energy and cost but also helps in moisture conservation. The practice of "set line cultivation" adopted in some dry regions is an example of minimum tillage. Here the seed row space is fixed and season after season, tillage is done only in this seeding strip. The intervening strip is not tilled.

5.2 Modern concepts of Tillage

In dry lands, rainfall is received simultaneously over a large area. In order to ensure timely sowing before soil dries up, the interval between land preparations and sowing must be narrowed down. This calls for completion of tillage over a large area in quick time. Dependence on bullock power and traditional wooden plough may not help in this regard. Use of more efficient tillage implements and mechanization of tillage operations are warranted.

Tillage in drylands also encompasses land shaping for *in situ* soil moisture conservation. Implements that can carryout tillage and land shaping in one single operation will help in saving time and cost. If land preparation, land shaping and sowing can be done in one single operation it can save considerable time. This is termed as once over tillage, plough planting or conservation tillage. Suitable tractor drawn machinery like a broad bed former cum seeder, Basin lister cum seeder which can complete the land shaping and sowing simultaneously can be used.

a) Minimum/optimum/reduced tillage: It is the tillage system aimed at reducing the number of tillage operations to the minimum level i.e. necessary for better seed bed preparation, rapid germination for maintenance of optimum plant stand. It not only saves time, energy and cost but also helps in moisture conservation. The objectives of these systems include (1) reducing energy input and labour requirement for crop production (2) conserving soil moisture and reducing erosion (3) providing optimum seedbed rather than homogenizing the entire soil surface, and (4) keeping field compaction to minimum .The advantages are:

i) Reduction of soil compaction

ii) Reduction of soil erosion

iii) Increases infiltration of water

iv) Increased soil fertility due to decomposition of crop residues

v) Less cost of production because less number of tillage operations

Disadvantages are

i) Reduced seed germination

ii) Root nodulation is affected in certain crops

iii) More nitrogen is required to enhance mineralization process

iv) Require specially designed equipment

Forms of minimum tillage

i) Row zone tillage: After the primary tillage with plough, the harrowing is done only in crop row zone

ii) Plough plant tillage: After primary tillage special planter is used for pulverising the soil, sowing the seed and covering the seed

iii) Wheel track planting: After primary tillage the tractors are used by their wheels, for pulverisation, sowing and covering of seed.

b) Conservation/mulch tillage: The objectives are to achieve soil and water conservation and energy conservation through reduced tillage operations. Both systems usually leave crop residue on the surface and each operation is planned to maintain continuous soil coverage by residue or growing plants. The conservation tillage practices may advance some of the goals of alternative farming such as increasing organic matter in soil and reducing soil erosion, but some conservation tillage practices may increase the need for pesticides. Conservation tillage changes soil properties in ways that affect plant growth, and reduce water runoff from fields. The mulched soil is cooler and soil surface under the residue is moist, as a result many conservation tillage systems have been successful.

c) Zero tillage or no-till system It is an extreme form of minimum tillage where primary tillage is completely avoided and secondary tillage is is resricted to crop zone.In this method use of mechinery and hebicides with relatively low or no residual effect on the crop to be established will play a major role.The mechinery should have attachments for four operations namely, cleaning the narrow strip over crop row,open the soil for seed insertion,placing the seed and covering the seed.

Advantages are

i) Increases the biological activity in the soil

ii) Organic matter content of the soil is increase due to decomposition of crop residues

iii) reduction of suface runoff

Diadavantages are

i) poor seed germination

ii) High dose of N required for mineralisation

iii) Some perennial weeds and voluntary plants predominate

iv) More disease and pest incidence

5.3 Seeding practices

5.3.1 Establishment of optimum population

Poor or suboptimal population is a major reason for low yields in rainfed crops. Establishment of an optimum population depends on

a) Seed treatment

b) Sowing at optimum soil moisture

c) Time of sowing

d) Depth of sowing

e) Method of sowing

f) Crop geometry

a) Seed treatment

Seed treatment is done for many purposes such as protection against pests and diseases, inoculation of bio-fertilizers and inducing drought tolerance.

i) Seed hardening

It is done to induce drought tolerance in emerging seedlings. It is the process of soaking seeds in chemical solution and drying to induce tolerance to drought. Soil moisture stress immediately after sowing affects germination and establishment. Seed hardening enables seedlings to survive this early moisture stress.

During seed hardening, seeds are subjected to partial hydration followed by dehydration before sowing. Seeds are soaked for specified time in chemical solutions of prescribed concentration. Soaked seeds are then dried in shade back to original moisture content. During soaking, seeds imbibe water and germination process is started but not completed. The hardened seeds are thus in a ready state for germination. When sown in moist soils, seeds germinate immediately. Such early germination helps in seedling emergence before surface soil dries up.

b) Sowing at optimum soil moisture

An effective rainfall of 20-25 mm which can wet a depth of 10-15 cm is needed for sowing. Moisture stress at or immediately after sowing adversely affects germination and establishment of seedlings. To ensure adequate soil moisture at sowing, sowing has to be done as early as possible after soaking rainfall is received. Sowing methods and implements play a crucial rile in this regard.

c) Time of sowing

Optimum time of sowing is indicated by adequate rainfall to wet seeding depth and continuity of rainfall after sowing. The probable sowing time in a rainfed area is the week which has a rainfall of not less than 20 mm with coefficient of variability less than 100% and the probability of a wet week following wet week. Timely sowing ensures optimal yield besides it may also help pest avoidance. In Maharastra *kharif* sorghum cultivated in 30 lakh hectares and more than 70% under hybrid prone to shoot fly. If sown at early July, the pest incidence can be avoided.

Pre-monsoon dry seeding

In some regions, where heavy clay soils dominate, sowing after rains is impossible due to high stickiness of soil. Here sowing is done in dry soil, 2-3 weeks before the onset of monsoon (pre-monsoon). Seeds will remain in soil and germinate only on receipt of optimum rainfall.

The advantages of pre-monsoon dry seeding are

i) Early sowing

ii) Uniform germination and good establishment

iii) Utilization of first rainfall itself for germination instead of for land preparation in post monsoon sowing

iv) Early maturity before closure of monsoon and avoidance of stress at maturity.

The success of pre-monsoon dry seeding depends on the following

i) It is recommended for bold seeds like cotton and sorghum only and not for all crops.

ii) Time of advance sowing must be fixed based on rainfall analysis for date of onset of monsoon and continuity of rainfall after sowing.

iii) Seeds must be hardened to ensure quick germination and drought tolerance

iv) Seeding depth must be such that seeds will germinate only after receipt of rainfall to wet that depth is received. Surface sowing may lead to germination with less rainfall and death due to subsequent soil drying.

v) Off season tillage is necessary to enable sowing in dry soil before monsoon

vi) Seed damage by soil insects has to be prevented

Examples of pre-monsoon sowing

1. For sorghum in black soils, pre-monsoon dry seeding is recommended 1-2 weeks before onset of monsoon with depth of sowing at 5 cm and seed hardening with 2 per cent potassium di-hydrogen phosphate or potassium chloride.

2. For cotton in black soils, pre-monsoon dry seeding is recommended at 2-4 weeks before commencement of monsoon, with a sowing depth of 5 cm and seed hardening with CCC (500 ppm) or potassium chloride or DAP at 2% level.

d) Optimum depth of sowing

When seeds are sown on surface or at very shallow depth, germination and seedling growth are affected when surface soil moisture dries up. Sowing at a depth where soil moisture availability is adequate, ensure early and uniform germination and seedling establishment. Optimum depth of' sowing varies with crop, especially seed size and penetration power of plumule.

Sesamum	1-2 cm
Pearl millet and minor millets	2-3 cm
Pulses, sorghum, sunflower	3-5 cm
Cotton, maize	5 cm
Coriander	7 cm

e) Method of sowing: In dry lands, it is important to sow the seeds in moist soil layer to ensure proper germination and seedling emergence. It is therefore necessary to sow immediately after rainfall to avoid sowing in dry soil. It is also important to sow the seeds at correct depth, neither on the surface nor too deep. Establishment of an optimum population also depends on proper spacing between plants. The density, geometry, and depth of sowing are dependent on method of sowing. The sowing methods usually adopted in dry lands include broadcasting, sowing behind plough and sowing by seed drills. Dibbling of seeds and planting of seedlings are also adopted for some crops (Cotton, tobacco, chillies). Each method has advantages as well as limitations. The choice of sowing method depends on seed size, soil condition, time available, cropping system, crop geometry, sowing depth, source of power, cost of sowing, etc.

Merits and limitations of sowing methods

Sowing method	**Merits**	**Limitations**
Broadcasting	Quick coverage for small seeds like - ragi, sesamum, minor millets, medium sized seed like sorghum, pulses can also be broadcasted	Spacing and depth not ensured High seed rate, intercrop sown separately
Sowing behind plough	For medium and bold seeds like cotton, sorghum, maize, groundnut, pulses, castor, sunflower etc., Seeding requires wooden plough only. Easy operation, row spacing can be ensured	Low coverage-spacing between plants and depth of sowing not ensured. Intercrop has to be sown separately. Only monsoon sowing is possible
Local seed drill (gorru)	For medium and bold seeds wooden implement, easy maintenance, less cost, row spacing is ensured, more coverage than broadcasting and sowing behind plough. Sowing depth and row spacing is uniform	Spacing between plants is not uniform and depends on experience of seed dropper. Intercrop has to be sown separately. Cannot be used for pre-monsoon sowing.
Mechanised seed drill (Bullock drawn/tractor drawn)	Large coverage, row and plant spacing ensured, uniform depth of sowing. Base crop and intercrop sown simultaneously. Enables early sowing in large area, saves cost and time. Pre monsoon sowing is possible.	Initial cost is high, needs skill for operation and maintenance.

f) Crop geometry: Crop geometry refers to the shape of land occupied by individual plants as decided by spacing between rows and between plants. It depends on the root spread and the canopy size of the crop and the cropping system.

Crop	Crop geometry (cm)	
	Sole crop in solid row	**Intercropping**
Sorghum	45 x 15	(60+30) x 15 paired row
Pearl millet	30 x 15	
Ragi	30 x 10	
Small millets	30 x 10	
Black gram, green gram, Soybean, horsegram	30 x 10	
Redgram	60 x 30	
Cowpea	30 x 15	
Cotton	45 x 30	(60+30) x 15 in paired row
Cotton (*Arboreum*)	45 x 15	
Groundnut	30 x 10	
Sesamum	30 x 30	
Sunflower	45 x 15	
Sunflower hybrids	45 x 20	
Sunflower varieties	30 x 15	
Coriander	30 x 15	
bengalgram	45 x 15	
Maize	45 x 30	

5.4 Setline cultivation: It is a form of minimum tillage practice predominant in saurastra region of India where farmers are adopting the practice of continuously cultivating, manuring and sowing wide spaced crops in the same line or row year after year. In between the rows the soil is worked with blade or harrowed only for weed control. The crops like sorghum, bajra, cotton, and groundnut are cultivated by this method. The advantages are

i) Reduced cost of cultivation

ii) As the crops are raised in the same row, the rhizosphere is loose with good aeration and permeability without development of hard pans in the sub soil

5.5 Soil crusts: Soil crusts are hard layers that develop at the soil surface due to action of rain drop or irrigation water and subsequent drying. Soil crusts often hinder the emergence of seedlings and hence establishment of crop stand.

Crust formation: The impact of rain and or irrigation disrupts the soil aggregates, reduces the mean size of the structural units and causes resorting and repacking by water movement in splash flow and sedimentation process. On subsequent drying it results in the development of continuous layer of closely packed soil particles. The crust has high bulk density, lower macro porosity and higher mechanical strength than below.

Effects of crust on soil and crop

i) Reduce infiltration rate

ii) Increase runoff and erosion

iii) Impede emerging seedling

iv) Injure the young seedling by movement of large blocks of crusts during cultivation

Management practices to avoid crust problem

i) Shallow and dense sowing

ii) Use of thorny bush harrowing

iii) Mulching

iv) Light harrowing after rain

v) Planting on shallow furrows and on sides of ridges

Lecture No. 6 Soil erosion- types of soil erosion and factors affecting soil erosion

6.1 Definition

Soil erosion is the process of detachment of soil particles from the top soil and transportation of the detached soil particles by wind and / or water.

The agents causing erosion are wind and water. The detaching agents are falling raindrop, channel flow and wind. The transporting agents are flowing water, rain splash and wind.

6.2 Nature and extent of erosion

The problem of soil erosion exists all over the country. Out of the 329 m.ha of India's geographical area about 175 m.ha (53.3%) is subjected to soil erosion and some kind of land degradation (Druvanarayana, 1993). About 150 m.ha is subjected to wind and water erosion. It is estimated that about 5333 Mt of soil is detached annually by soil annually. Out of this 29 % is carried away by rivers to seas and about 10% is deposited in reservoirs resulting in 1-2 % of loss of storage capacity annually. The estimated annual soil loss is 16.35 tones/ha/year.

Physiographically India is divided into three regions as follows:

a) **Himalayan region**: Geologic immaturity made this region more vulnerable to erosion. High degree of seismicity of the area, very steep slopes, weak geological formation and improper land use practices accelerate erosion losses. Gullying, land slides and slips are most common.

b) **Gangetic plains**: Major problems in the region are riverine erosion, drainage, saline and alkali soil conditions.

c) **Peninsular region**: Main problems of this region are rill and gully erosion.

Arid regions have severe wind erosion. Semi arid regions are subjected to sheet and gully erosion and ravines are serious problem in Yamuna and Chambal region. Floods and stream bank cutting and sand deposition have degraded lands of north east region with heavy rainfall. South and south east are characterized by undulating terrain with severe erosion in black and red laterite soils.

6.3 Losses due to erosion:

i) Loss of fertile top soil

ii) Loss of rain water

iii) Loss of nutrients

iv) Silting up of reservoirs

v) Damage to forests

vi) Reduction in soil depth

vii) Floods

viii) Adverse effect on public health

ix) Loss of fertile land

x) Economic losses

6.4 Types of erosion:

There are two major types of soil erosion

a) Geological erosion (Natural or normal erosion): is said to be in equilibrium with soil forming process. It takes place under natural vegetative cover completely undisturbed by biotic factors. This is very slow process.

b) Accelerated erosion: is due to disturbance in natural equilibrium by the activities of man and animals through land mismanagement, destructing of forests over grazing etc., Soil loss through erosion is more than the soil formed due to soil forming process.

Based on the agents causing erosion, erosion is divided into

a. Water erosion b. Wind erosion c. Wave erosion

6.4.1 Water erosion

Loss of soil from land surface by water including run off from melted snow and ice is usually referred to as water erosion.

Major erosive agents in water erosion are impacting/ falling raindrops and runoff water flowing over soil surface.

6.4.1.1 Process of water erosion

Detachment of soil particles is by either raindrop impact or flowing water. Individual raindrops strike the soil surface at velocities up to 9 m/s creating very intensive hydrodynamic force at the point of impact leading to soil particle detachment. Over land flow detaches soil particles when their erosive hydrodynamic force exceeds the resistance of soil to erosion. Detached soil particles are transported by raindrop splash and runoff. The amount of soil transported by runoff is more than due to raindrop splash. Thus the falling raindrops break the soil aggregates and detach soil particles from each other. The finer particles (silt and clay) block the soil pores and increase the rate of runoff and hence loss of water and soil.

6.4.1.2 Forms of water erosion

Water erosion occurs in stages identified as sheet erosion, rills, gullies, ravines, landslides and stream bank erosion.

a) Sheet erosion: It is the uniform removal of surface soil in thin layers by rainfall and runoff water. The breaking action of raindrop combined with surface flow is the major cause of sheet erosion. It is the first stage of erosion and is least conspicuous, but the most extensive.

b) Rill erosion: When runoff starts, channelisation begins and erosion is no longer uniform. Raindrop impact does not directly detach any particles below flow line in rills but increases the detachment and transportation capacity of the flow. Rill erosion starts when the runoff exceeds 0.3 to 0.7 mm/s. Incisions are formed on the ground due to runoff and erosion is more apparent than sheet erosion. This is the second stage of erosion. Rills are small channels, which can be removed by timely normal tillage operations.

c) Gully erosion: It is the advanced stage of water erosion. Size of the unchecked rills increase due to runoff. Gullies are formed when channelised runoff form vast sloping land is sufficient in volume and velocity to cut deep and wide channels. Gullies are the spectacular symptoms of erosion. If unchecked in time no scope for arable crop production.

d) Ravines: They are the manifestations of a prolonged process of gully erosion. They are typically found in deep alluvial soils. They are deep and wide gullies indicating advanced stage of gully erosion.

e) Landslides: Landslides occur in mountain slopes, when the slope exceeds 20% and width is 6m. Generally land slides cause blockage of traffic in ghat roads.

f) Stream bank erosion: Small streams, rivulets, torrents (hill streams) are subjected to stream bank erosion due to obstruction of their flow. Vegetation sprouts when streams dry up and obstructs the flow causing cutting of bank or changing of flow course.

6.4.1.3 Factors affecting water erosion

a) Climate: Water erosion is directly a function of rainfall and runoff. Amount, duration and distribution of rainfall influences runoff and erosion. High intensity rains of longer duration causes severe erosion. Greater the intensity, larger the size of the raindrop. Rainfall intensity more than 5 cm/hr is considered as severe. Total energy of raindrops falling over a hectare land with rainfall intensity of 5 cm /hr is equal to 625 H.P. This energy can lift 89 times the surface 17.5 cm of soil from one ha to a height of 3 ft. Two- thirds of the above energy is used for sealing soil pores. Runoff may occur without erosion but there is no water erosion without runoff. The raindrop thus breaks down soil aggregates, detaches soil particles and leads the rainwater with the fine particles. These fine particles seal the pores of the surface soil and increases runoff causing erosion.

b) Topography: The degree, length and curvature of slope determine the amount of runoff and extent of erosion. Water flows slowly over a gentle slope where as at a faster rate over a steeper one. As water flows down the slope, it accelerates under the forces of gravity. When runoff attains a velocity of about 1 m/s it is capable of eroding the soil. If the percent of slope is increased by 4 times the velocity of water flowing down is doubled. Doubling the velocity quadruples the erosive power and increases the quantity of soil that can be transported by about 32 times and size of the particles that can be transported by about 64 times.

c) Vegetation: Vegetation intercepts the rainfall and reduces the impact of raindrops. It also decreases the velocity of runoff by obstructing the flow of water. The fibrous roots are also effective in forming stable soil aggregates, which increases infiltration and reduces erosion.

d) Soil Properties: Soil properties that influence soil erodability by water may be grouped into two types.

i. Those properties that influence the infiltration rate and permeability

ii. Those properties that resist the dispersion, splashing, abrasion and transporting forces of rainfall and runoff.

The structure, texture, organic matter and moisture content of upper layers determine the extent of erosion. Sandy soils are readily detachable but not readily transportable. Soils of medium to high clay content have low infiltration capacities and they are readily transported by water after they are dispersed, but their detachability is generally low.

e) Man and beast

Man and beast accelerates erosion by extensive farming and excessive grazing. Faulty practices like cultivation on steep slopes, cultivation up and down the slope, felling and burning of forests etc., leads to heavy erosion. Excessive grazing destroys all vegetation and increases the erosion.

6.4.1.4 Estimation of soil loss by water erosion

Based on the mechanism and factors influencing soil erosion, a universal soil loss equation (USLE) developed by Wischmeier (1959) is most useful for predicting soil loss due to water erosion. It is an empirical equation and estimates average annual soil loss per unit area as a function of major factors affecting sheet and rill erosion. It enables determination of land management erosion rate relationships for a wide range of rainfall, soil slope and crop and management conditions and to select alternative cropping and management combinations that limit erosion rates to acceptable limits.

$$A = R \times K \times L \times S \times C \times P$$

where, A= predicted soil loss in t/ha/year

R= rainfall erosivity factor or index

K= soil erodibility factor

L= length of slope factor

S= slope steepness factor

C= soil cover and management factor and

P= erosion control factor

6.5 Wind erosion

Erosion of soil by the action of wind is known as wind erosion. It is a serious problem on lands devoid of vegetation. It is more common in arid and semi arid regions. It is essentially a dry weather phenomenon stimulated by the soil moisture deficiency. The process of wind erosion consists of three phases: initiation of movement, transportation and deposition. About 33 m.ha in India is affected by wind erosion. This includes 23.49 m.ha of desert and about 6.5 m.ha of coastal sands. The Thar Desert is formed mainly by blow in sand.

6.5 Mechanism of wind erosion

Lifting and abrasive action of wind results in detachment of tiny soil particles from the granules or clods. The impact of these rapidly moving particles dislodge other particles from clods and aggregates. These dislodged particles are ready for movement. Movement of soil particles in wind erosion is initiated when the pressure by the wind against the surface soil grains overcomes the force of gravity on the grains. Minimum wind velocity necessary for initiating the movement of most erodable soil particles (about 0.1 mm diameter) is about 16 km /hr at a height of 30.5 cm. Most practical limit under field conditions, where a mixture of sizes of single grained material present is about 21 km/hr at a height of 30.5 cm.

In general movement of soil particles by wind takes place in three stages: saltation, surface creep and suspension.

a. **Saltation:** It is the first stage of movement of soil particles in a short series of bounces or jumps along the ground surface. After being rolled by the wind, soil particles suddenly leap almost vertically to form the initial stage of movement in saltation. The size of soil particles moved by saltation is between 0.1 to 0.5 mm in diameter. This process may account for 50 to 70% of the total movement by wind erosion.

b. **Surface creep**: Rolling and sliding of soil particles along the ground surface due to impact of particles descending and hitting during saltation is called surface creep. Movement of particles by surface creep causes an abrasive action of soil surface leading to break down of non-erodable soil aggregates. Coarse particles longer than 0.5 to 2.0 mm diameter are moved by surface creep. This process may account for 5 to 25% of the total movement.

c. **Suspension:** Movement of fine dust particles smaller than 0.1 mm diameter by floating in the air is known as suspension. Soil particles carried in suspension are deposited when the sedimentation force is greater than the force holding the particles in suspension. This occurs with decrease in wind velocity. Suspension usually may not account for more than 15% of total movement.

Lecture No. 7 Soil conservation measures – agronomic measures of soil conservation

7.1 Definition of soil conservation

Soil conservation is using and managing the land based on the capabilities of the land itself involving application of the best management practices leading to profitable crop production without land degradation.

7.2 Control of water erosion

Water erosion occurs simultaneously in two steps: detachment of soil particles by falling raindrops and transportation of detached particles by flowing water. Hence preventing the detachment of soil particles and their transportation can minimize water erosion. Principles of water erosion control are

- Maintenance of soil infiltration capacity
- Soil protection from rainfall
- Control of surface runoff and
- Safe disposal of surface runoff

For a sound soil conservation programme every piece of land must be used in accordance with the land capability classification.

7.2.1 Measures of water erosion control

1. Agronomic measures
2. Mechanical measures (Engineering measures)
3. Forestry measures
4. Agrostological measures

7.2.2 Agronomic measures of soil conservation

In soil and water conservation programmes agronomic measures have to be considered in co-ordination with others for their effectiveness. These measures are effective in low rainfall areas particularly in fairly erosion resistant soils having gentle slope (< 2 %).

The different agronomic measures include

1. Land preparation
2. Contour cultivation
3. Choice of crops
4. Strip cropping
5. Crop rotation / cropping systems
6. Cover crops
7. Mulching
8. Application of manures and fertilizers
9. Application of chemicals

a) Land preparation: Land preparation including post harvest tillage influence intake of water, obstruction to surface flow and consequently the rate of erosion. Deep ploughing or chiseling has been found effective in reducing erosion. Rough cloddy surface is also effective in reducing erosion.

b) Contour cultivation (Contour farming): A line joining the points of equal elevation is called contour. All the cultural practices such as ploughing, sowing, intercultivation etc. done across the slope reduce soil and water loss. By ploughing and sowing across the slope, each ridge of plough furrow and each row of the crop act as obstruction to the runoff and provide more time for water to enter into the soil leading to reduced soil and water loss (Fig 7.1).

Fig 7.1 Contour Cultivation

c) Choice of crops :Row crops or tall growing crops such as sorghum, maize, pearl millet etc.,are not effective in conserving soil as they expose majority of the soil and hence they are known as **erosion permitting crops.** Where as close growing crops such as cowpea, groundnut, green gram, black gram etc., which protect soil are known as **erosion resisting crops** as they are very effective in reducing soil loss by minimizing the impact of rain drop and acting as obstruction to runoff.

d) Strip cropping: It is a system of growing of few rows of erosion resisting crops and erosion permitting crops in alternate strips on contour (across the slope) with the objective of breaking long slopes to prevent soil loss and runoff. Close growing erosion resisting crops reduce the transporting and eroding power of water by obstructing runoff and filtering sediment from runoff to retain in the field. The width of the erosion permitting and erosion resisting crops vary as per the slope of the field. The strip cropping resembles the intercropping.

Slope (%)	**Width of crops (m)**	
	Erosion resisting	**Erosion permitting**
Up to 1%	9.0	45.0
1 to 2%	6.0	24.0
2 to 3%	4.0	12.0

With increase in per cent slope of the soil, the width of erosion permitting and erosion resisting crops decreases. The normal ratio between the erosion resisting crops and erosion permitting crops is 1: 3. Among the different crops the anti-erosion value of pillipesara is highest, where as cotton crop recorded the lowest value .The strip cropping is divided into four types as follows

i) Contour strip cropping: The erosion permitting crops and erosion resisting crops are grown in alternate strips along the contours.

ii) Field strip cropping: Alternate strips of erosion permitting crops and erosion resisting crops are raised across the general slope not necessarily on exact contour

iii) Wind strip cropping: Strip cropping of erosion permitting and erosion resisting crops across the direction of the most prevailing wind irrespective of the contour.

iv) Buffer strip cropping: this type of strip cropping is practiced in areas having steep slopes and badly eroded soils where strips of permanent cover crops or perennial legumes or grasses or shrubs are alternated with field crops.

The strip cropping is simple, cheap and effective soil conservation practice and can be adopted by the farmers.

e) Crop rotation / cropping system: Monocropping of erosion permitting crops accelerates soil and water loss year after year. Intercropping of erosion permitting crops and erosion resisting crops or their rotation has been found effective for reducing soil and water loss. Inclusion of legumes like lucerne in crop rotation reduces soil loss even in soils having 13% slope.

f) Cover crops: Good ground cover by canopy gives the protection to the land like an umbrella and minimize soil erosion. Besides conserving soil and moisture, the cover crops hold those soluble nutrients, which are lost by leaching. The third advantage of the cover crops is the addition of organic matter. The legumes provide better cover and better protection. Among the legumes cowpea has been found to produce maximum canopy followed by horsegram, green gram, black gram and dhaincha.

g) Mulching: Mulching of soil with available plant residues reduce soil loss considerably by protecting the soil from direct impact of raindrop and reducing the sediment carried with runoff .A minimum plant residue cover of 30 per cent is necessary to keep runoff and soil loss within the acceptable limits. Vertical mulching also reduce soil loss particularly in vertisols by increasing infiltration.

h) Application of manures and fertilizers : Organic manures besides supplying nutrients improve soil physical conditions thereby reduce soil loss. Fertilizers improve vegetative canopy, which aid in erosion control.

i) Use of chemicals: Breakdown of aggregates by the falling raindrops is the main cause of detachment of soil particles. Soils with stable aggregates resist breakdown and thus resist erosion. Aggregate stability can be increased by spraying chemicals like poly vinyl alcohol @ 480 kg/ha (rate will depend on the type of soil). Soils treated with bitumen increase water stable aggregates and infiltration capacity of the soil.

Lecture No. 8 Fertilizer use in drylands

8.1 Introduction

No Agricultural system can persist, if it fails to maintain soil fertility. In dryland soils or SAT soils Nitrogen is universally deficient, 'P' is low, and 'K' status is medium to high. The organic matter content of SAT soils is usually less than one per cent and hence is of low fertility status.

8.2 Low rates of fertilizer application

Vagaries of rainfall and consequent uncertainty of crop performance make farmers of dryland agriculture to avoid fertilizer application. However, results of experiments demonstrated yield advantage due to fertilizer use in dry land crop production.

If the fertilizers are applied to meet the needs of the dryland crops, there may be prolonged breaks in the monsoon in *kharif* or limited available moisture in the root zone of *rabi* crops may be exhausted before the plants reach reproductive stage resulting in poor yields. On the other hand, if fertilizers are applied at rates below the optimum, the yields will be poor. This has to be avoided by assessing the yield potential of different regions and regulating the soil fertility levels by adding only such quantities of fertilizers as required for realizing the potential to the maximum extent possible. Hence fertilizer usage is more in irrigated agriculture than dryland agriculture.

8.3 Response to Nitrogen

Fertilizer use and loss will be more sensitive in shallow soils; hence response to applied fertilizer will be less stable on shallow soils. Response to 'N' was low and influence of rainfall was inconsistent among shallow vertisols and alfisols. With decreasing rainfall, vertisols produced more response to applied fertilizer.

Results indicated that with 40 kg N/ha many crops responded to 'N' in dryland areas by giving about 20 kg extra grain or yield for every kg of N applied. However, magnitude of response decreased with higher rates except maize crop. Results of experiments for five years indicated that response of *rabi* sorghum to 25 kg N/ha on soils with low moisture storage, where as on soil depth up to 60 cm sorghum grain yield increased up to 75 kg N/ha.

8.4 Response to Phosphorus

Deficiency of phosphorus is less extensive than that of nitrogen. Though several crops respond to 'P' the response is not conspicuous and universal as that of 'N'. Dry land vertisols possess high phosphorus fixation capacity, ranging from 300 to 450 mg /kg of soil, hence there will be less amount of 'P' in soil solution to be available for the crop plants. This explains the lack of response to 'P' in vertisols since the amount of the 'P' added seldom exceed 25-35 kg P_2O_5/ha which is inadequate to meet the 'P' fixing capacity of the soil and crop requirement. Response of dryland crops to 'P' will continue to remain small and marginal as long as the poor yields of crops are not increased through efficient soil and moisture conservation measures and balanced crop nutrition.

8.5 Response to Potassium

On a large scale, potassium has failed to produce distinct response in dryland cereals and millets as is common with irrigated crops. Dryland soils particularly, the sandy loam and red soils which are deficient in 'K' may respond to moderate levels of 'K' when monsoon is normal. The recommended dose of NPK for different crops of Andhra Pradesh in furnished in table 8.1

Table 8.1 : Recommended dose of fertilizers for rainfed crops of Andhra Pradesh

Crop	Dose (kg/ha)		
	N	P_2O_5	K_2O
Groundnut	20	40	40
Sorghum	40-80	40	0
Pearl millet	40-80	40	0
Setaria	40	40	0
Redgram	20	40	0
Greengram	20	40	0
Horsegram	10	30	0
Sunflower	30-40	30-40	0

8.6 Response to secondary and micronutrients

Among secondary nutrients oilseeds and pulses respond to sulphur and calcium. Response to ‘Ca’ and ‘S’ is of typical of rainfed groundnut. Among the micronutrients deficiency of ‘Fe’ and response to its application have been observed in crops like chickpea and groundnut. Zinc is deficient in many areas and many crops respond to Zinc Eg: groundnut, maize, pearl millet etc.

8.7 Response to NPK (Balanced fertilization)

Balanced fertilizer application increases the efficiency of added fertilizers. Response to universally deficient ‘N’ could be low if other nutrients are limiting. More frequently ‘P’ limits the response of ‘N’. If N+P is applied the yield response is increased.

In dryland areas receiving less than 750 mm annual rainfall where prolonged dry spells are common during the crop period, economical responses were obtained with low levels of ‘N’ only.

8.8 Alternate sources of Nitrogen

There are several alternate sources of ‘N’, which include organic manures, biofertilizers, green manuring, introduction of legumes in cropping system etc.,

8.9 Green manuring

This is considered normally uneconomical in drylands. In Khammam district of A.P, farmers raise green gram with June-July rains and after picking the pods, plough back the residue and take the sorghum by September (Maghi sorghum). It can be practiced in vertisols with dependable rainfall. Horsegram can be raised after sorghum or sunflower during October / November where there is dependable rainfall. The leaves of Soobabul, Glyricidia etc, can be used as green leaf manure.

8.10 Introduction of legumes in cropping systems

Legume, being a biological ‘N’ fixing crop, should become a part of the cropping system. Legumes in a cropping system contribute to the extent of 25 kg N/ha.

8.11 Organic recycling

Vast potential for organic wastes like stubbles of millets and other crops, sugarcane trash, weeds and other farm residues exist in many areas, which can put to agricultural use by composting. Conjunctive use of FYM and these organic wastes improve the productivity of soils especially sandy loam soils by improving their moisture retentive capacity.

8.12 *Rhizobium* culture

Inoculating legumes with *Rhizobium* could not met with success for increasing 'N' fixation under dryland conditions probably due to unfavourable environment, especially prolonged soil moisture stress periods during crop season, high temperature stress and deficiency of other nutrients.

8.13 Integrated nutrient management system

It envisages the conjunctive use of organic manures, crop residues, biofertilizers, legumes in crop rotation, green manuring and need based chemical fertilizers for sustained crop production.

Mean yield of finger millet over a period of 9 years was similar with recommended NPK rates or with 50% NPK fertilizers along with FYM 10 t/ha. At Akola (Maharastra) and Kovilpatti (Tamilnadu) incorporation of organic residues increased sorghum yield by 120 and 75 kg/ha as against 75 and 38 kg / ha with fertilizers.

Biofertilizers like *Azospirillum* commonly found in association with roots of cereals and grasses. High N fixation capacity, low energy requirement and abundant establishment in the roots of cereals and tolerance to high temperature (30-40° C) are responsible for its suitability to dry land conditions. It has been largely tested in sorghum and bajra and can substitute up to 20 kg N/ha.

VAM: Vesicular Arbuscular Mycorrhizae has found to influence yield of several crops like bajra, finger millet, sorghum, groundnut, pegionpea, cowpea etc. by increasing 'P' uptake.

Phosphate Solubulising Bacteria (PSB) also recieved considerable attention. Eg: *Bacillus* sps.

8.14 Salient findings of fertilizer use research in dry land agriculture

The results of fertilizer use research in dry farming areas indicated that fertilizer dose should be low. Improved cultivars are responsive than local varieties.

The following are the salient findings of research on fertilizer use under rainfed conditions:

1. Response of crops to fertilizers varied with available soil moisture. Higher the rainfall, greater the response in shallow soils.
2. Responses to 'N' are universal, responses to 'P' are obtained on alfisols, and responses to 'K' are limited.
3. Response of post-rainy season crops i.e. *rabi* crops to fertilizers will depend on stored moisture in the profile. Most of the nutrients have to be band placed in the soil at sowing as basal application.
4. For kharif crops, nitrogen can be applied in splits depending on rainfall. Second split may be avoided if the soil moisture is not adequate for top dressing in time.
5. Zinc deficiency is indicated in some areas.
6. Balanced fertilizer use resulted in yield advantage during normal rainfall years.
7. Legumes are more responsive to 'P' fertilization.
8. Foliar application of nutrients was not beneficial at several places.
9. Most economical responses were with low rates of 25-30 kg N/ha.
10. On heavy black soils, crops respond to about 30 kg P_2O_5/ha.
11. Legumes in cropping system contribute to the extent of about 25 kg N/ha and
12. Integrated nutrient management system appears to be more remunerative.

8.15 Fertilizer use efficiency (FUE) in dryland agriculture

It refers to kg of produce per kg of plant nutrient fertilizer applied.

8.15.1 Factors affecting fertilizer use efficiency

- Choice of cultivars or varieties or varietal selection
- Timely sowing
- Establishment of adequate crop stand
- Time and method of fertilizer application
- Moisture conservation practices and
- Timely weed management

a. Choice of varieties: Choice of varieties will depend on length of the growing season. The traditional varieties are of long duration and their productivity is low. High yielding and short duration varieties give more yields and increase the fertilizer use efficiency.

b. Timely seeding: Timely sowing of a crop is an important agronomic factor influencing crop yield and therefore the response to fertilizer application. Early seeding gives good seedling vigour and longer growing season thereby leading to efficient use of applied fertilizers resulting in higher yields. Delayed sowings in drylands drastically reduce the yields due to terminal soil moisture stress both in rainy season and post rainy season crops. Optimum sowing time for rainy season crops in South India is from June to mid July and post rainy season crops is early September. Prasad *et al*., (1988) reported that there is more than 50% reduction in wheat yields in all the Agro climatic zones of the country when sowings were delayed from mid November to first fortnight of January. To make up the yield loss due to delay in sowing, the usual recommendations are higher rate of fertilizer application leading to low fertilizer use efficiency.

c. Adequate crop stand : One of the major factors for low yields in most of the crops is inadequate plant population, which is due to inadequate available soil moisture and soil crusting. The genetical potential of a cultivar is achieved only when optimum plant population is provided for efficient use of the applied fertilizer. Plant population of 67,000 plants/ha (in winter maize) application of 200 kg N /ha gave the same yield as obtained with only 100 kg N/ha at the population of 83000 plants/ha.

d. Time of fertilizer application: Entire phosphorus and potassium requirements of both kharif and *rabi* crops are generally applied as basal dose. Split application of N has been proved to be effective for *kharif* on light soils. If rains are not received in time, fertilizer intended for top dressing can be saved. However for *rabi* crops grown on stored soil moisture entire N has to be applied at sowing as the chances of receiving rains after sowing are limited. Fertilizer rates based on the amount of stored moisture will be more effective than blanket rates.

e. Method of fertilizer application: Placement of P fertilizer near the plant row proved to be better than the broadcasting in increasing FUE. It is of greater importance in crops grown on receding soil moisture during post rainy season. This placement is normally done by seed cum ferti drills.

f. Moisture conservation: Soil moisture is the most limiting factor in dryland agriculture. Fertilizer use efficiency and water use efficiency are mutually complementary. Several moisture conservation methods like setline cultivation, vertical mulch, BBF, recycling of runoff has been recommended for increasing the FUE.

g. Timely weed control: Weed control has a major impact on crop yield in dry lands. Weeds compete with crop plants for moisture and nutrients and reduce the crop yields by 30 to 60%. Keeping the fields weed free especially at early stage of the crop growth, has given maximum benefits by way of efficient use of scarce soil moisture leading to higher fertilizer use efficiency and higher yields.

Lecture No. 9 Choice of crops and varieties – cropping systems in drylands

9.1 Choice of crops

Traditional cropping pattern in the dry farming areas is dominated by food grains *viz.,* millets and pulses. In a predominantly subsistence type of farming system, such dominance of food crops is natural. The choice of crops for drylands is affected by

- Rainfall quantity and distribution
- Time of onset of rainy season
- Duration of rainy reason
- Soil characters including amount of rain water stored in the soil
- Farmer's requirements

The major focus of research under AICRPDA has been on the identification of most efficient crops for each dry farming region. The criteria for choice of crops for dry farming regions comprise the following

- Tolerance to drought
- Fast growth during initial period to withstand harsh environment
- Genetic potential for high yield
- Short or medium duration to escape terminal drought
- Adaptability to wide climatic variations
- Responsive to fertilizers

For many dry farming regions of India, more suitable crops than existing ones have been identified. However, the acceptance and adoption of the practice of crop substitution by dry land farmers is poor since in most instances the new crops replace food crops (Table 9.1).

Table 9.1 Suggested crops in place of traditional crops

Region	Traditional crop	Yield (q/ha)	More suitable crop	Yield (q/ha)
Agra	Wheat	10.3	Mustard	20.4
Bellary	Cotton	2.0	Sorghum	26.7
Bijapur	Wheat	9.4	Safflower	18.8
Varanasi	Upland rice	28.0	Maize	33.8

9.2 Selection of suitable varieties

In most crops of dry farming regions, traditional local varieties still dominate. The preference for these local varieties is based on their pronounced drought tolerance. But they are usually longer in duration susceptible to moisture stress at maturity. They have low yield potential even under favourable rainfall. They do not respond significantly to improved management practices such as nutrient supply. The criteria now adopted for selection of crop varieties for dry lands include drought tolerance, short or medium duration, high yield potential, response to nutrient supply, high water use efficiency, moderate resistance to pest and diseases. Suitable varieties for all dry land crops have been developed in all the dry farming regions and have proved their high yield potential.

9.3 Choice of cropping system

Choice of suitable cropping system must aim at maximum and sustainable use of resources especially water and soil. Cropping systems depend on rainfall quantity, length of rainy reason and soil storage capacity. The broad guidelines in choosing a cropping system for dry lands are given below (Table 9.2).

Table 9.2 Potential cropping systems based on rainfall and soil characters

Rainfall (mm)	Soil type	Growing season (weeks)	Profile storage capacity (mm)	Suggested cropping system
350-600	Alfisols, shallow vertisols	20	100	Single rainy season cropping sorghum / maize / soybean
350-600	Deep aridisols, Entisols(alluvium)	20	100	Single cropping sorghum / maize / soybean in kharif / rabi
350-600	Deep vertisols	20	100	Single post rainy season cropping sorghum
600-750	Alfisols, vertisols, entisols	20-30	150	Intercropping Sorghum + Pigeon pea Cotton + Black gram
750-900	Entisols, deep vertisols, deep alfisols, inceptisols	30	200	Double cropping with monitoring Maize – safflower Soybean – chick pea Groundnut – horsegram
> 900	As above	> 30	> 200	Assured double cropping Maize – chick pea Soybean - safflower

Crops and cropping systems selected should match the length of growing season during which they are not subjected to soil moisture stress. Climatalogical analysis helps to identify suitable cropping systems for different regions. Feasibility for intercropping, sequence cropping and double cropping can also be known from such analysis (Table 9.3).

Table 9.3 : Length of effective cropping season in different areas (Randhawa and Venkateswarulu, 1979)

Category	Effective cropping season(weeks) in different areas			Potential cropping system
< 20 weeks	Bellary (8) Hissar (17)	Jodhpur(11) Rajkot (17)	Anantapur (13) Bijapur (17)	Sole cropping
20-30 weeks	Jhansi (21) Udaipur (22) Anand (25)	Kovilpatti (21) Sholapur (23) Akola (27)	Hyderabad (22) Agra (24)	Intercropping
> 30 weeks	Bhubaneswar (32) Bangalore (36) Rewa (36) Samba (44)	Varanasi (32) Hoshiarpur (35) Ranchi (45)	Indore (36) Dehradun (44)	Sequence cropping

9.3.1 Monocropping

In general a single crop is being taken in dry farming areas where the annual rainfall is below 500 mm. Rainy season crop is taken in light soils like alfisols, inceptisols and oxisols. Crops are being grown on residual moisture in vertisols in the post rainy season in winter season. The most common monocropping systems are groundnut in alfisols and associated soils in Rayalaseema region of Andhra Pradesh, sorghum or chickpea or wheat in black soils of Madhya Pradesh, Andhra Pradesh, and Karnataka.

9.3.2 Intercropping

Intercropping refers to growing two or more crops in the same field with specific row arrangement during the same season. In areas where the annual rainfall is in the range of 600-850 mm, intercropping is being recommended and practiced. In such areas, at least one of the component crops succeeds in drought years and there is every chance to get two crops in good rainfall years. The different intercropping systems are followed in different regions of the country based on soil, rainfall, market price and marketing facilities. Intercropping systems are subject to change due to change in market price of component crops. Intercropping is widely practiced in dry farming since it offers many **advantages** as outlined below.

- Intercropping is a risk minimization strategy and provides an insurance against complete crop failure due to rainfall abnormalities.
- It provides more yield and income per unit area per unit time than sole cropping
- Stability in production is achieved
- Multiple products for home consumption as well as for marketing are made available
- When legumes are included in intercropping, soil fertility is enriched
- Intercrop canopy suppresses weed growth
- Resource use efficiency is increased viz., light, water and nutrients are efficiently used
- One crop provide physical support to other crop.

Disadvantages are

- Yield may be decreased due to competition effect
- Allelopathy effect
- Build up of certain diseases and pests
- May not be suitable for large farms with adequate resources

The different intercropping systems suitable for drylands are furnished in table 9.4 and 9.5.

Table 9.4 Inter cropping systems suitable for drylands

Crops	Geometry	Base crop duration (days)	Intercrop duration (days)
Sorghum + Lablab	6-8:2	100-120	150-180
Sorghum + Redgram	6-8:1	100-120	180
Sorghum + Cowpea	2:1	100-120	80
Cotton + Black gram	2:1	150-185	65-75
Groundnut + Redgram	6-8:1	105	180
Groundnut + Castor	6-8:1	105	150-180
Bengalgram + Coriander	4:1	100	80
Maize + Cowpea	2:1	100-110	75-80
Ragi+ Cowpea + Redgram	6:1:1	100	75 + 180

Table 9.5 Dominant intercropping systems in different regions of India

Location	Soil	Rainfall (mm)	Intercropping	Row ratio
Anantapur	Alfisols	550	Groundnut + pigeon pea	11 : 1
Akola	Vertisols	825	Sorghum + pigeon pea	2 : 1
Rajkot	Vertisols	590	Groundnut + castor	4: 1
Sholapur	Vertisols	560	Chickpea + safflower	3:1
Bangalore	Alfisols	890	Finger millet + pigeon pea	8:1

9.3.2.1 Efficient intercropping systems for different regions of Andhra Pradesh

a) For Telagana region:

Intercrop	Ratio
Pigeon pea + Blackgram	1:2
Groundnut + Castor	5:1
Sorghum + Pigeon pea	2:1
Castor + Cluster bean	1:1 or 2:2
Pigeon pea + Sunflower	1:2

Among the different intercropping systems in Telagana region, sorghum + pigeon pea (2:1) is the most efficient system which result in maximum returns.

b) Rayalaseema region:

Intercrop	**Ratio**
Groundnut + Blackgram	7:1
Groundnut + Castor	5:1 or 7:1
Groundnut + Pearl millet	2:1
Pearl millet + Pigeon pea	1:1 or 2:2
Pigeon pea + Sunflower	1:2

Among the different intercropping systems in Rayalaseema region, groundnut + pigeon pea (7:1) or groundnut + castor (5:1 or 7:1) was found to be the most efficient system which result in maximum returns.

9.3.3 Double cropping in drylands

Double cropping either by sequential cropping or relay cropping is possible in places with high rainfall (> 900 mm), extended rainy season and high soil moisture storage capacity. Double cropping is also possible with rain water harvested in farm ponds which is used for establishing winter crop. Some of the important double cropping systems of different regions are presented in Table 9.6 and 9.7.

Table 9.6 Important double cropping systems of different location

Location	Rainfall (mm)	Soils	Double cropping
Ranchi	1,370	Oxisols	Rice-linseed or chickpea
Indore	960	Vertisols	Soybean-Wheat
Pune	1,050	Vertisols	Rice-Chickpea
Bangalore	890	Alfisols	Cowpea-finger millet

Table 9.7 Efficient double cropping systems for drylands of India

Soil type	Region	Water availability (days)	Double cropping system
Vertisols	MP	210-230	Maize – chickpea Soybean – wheat
	Maharastra	190-210	Sorghum – safflower
	Karnataka	130-150	Cowpea – sorghum Greengram – safflower
Inceptisols	UP	200-230 180-200	Rice – Chickpea Pearl millet – chickpea Blackgram – mustard
Oxisols	Bihar	160-180	Maize – chickpea Groundnut – barley
Alfisols	Karnataka	190-220	Cowpea – ragi Soybean – ragi
Alfisols and aridisols		< 120	No double cropping

Double cropping by relay cropping

Groundnut / Ragi	+	Redgram	-	Horsegram
(Jun-Sep)		(Jun-Jan)		(Sep-Jan)

Groundnut or ragi is sown with redgram as intercrop in 6:1 proportion in June. After harvest of groundnut in September, horsegram is relay sown in the space between redgram rows.

Double cropping by sequential cropping

Pearl millet / ragi (finger millet)/ sama (little millet) (May – Sep)	Horsegram (Sep – Jan)
Groundnut / sesamum (May – Sep)	Horsegram (Sep – Jan)
Cowpea / greengram (Jun – Sep)	Sorghum (Oct – Jan)
Sorghum (Jul – Oct)	Chickpea (Oct – Feb)

Lecture No. 10 Contingent crop planning for aberrant weather conditions

10.1 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 10.1). 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 10.1 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

10.2 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 is normal 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 10.2).

Table 10.2 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 crops for different situations and regions of Andhra Pradesh and other states are suggested in Tables 10.3 and 10.4.

Table 10.3 Suggested contingency cropping for different situations in Andhra Pradesh

Time of onset of sowing rains	Crop	Varieties	Regions/situation
May	Sesamum	Madhavi, Gowri	Medium black soils, medium and deep red soils
June	Sorghum	CSH-5, CSH-9, CSH-10, CSH-11, CSV-1.1, CSV-12, SPV-462, SPV-475	Red soils, light black soils.
	Castor	Kranthi, Haritha	Telengana region
July	Groundnut	TMV. 2, Tirupati-1, Vemana,	Scarce rainfall zone of A.P.
August	Cotton	Mahanandi, NHH-4, Jayadhar, MCU-5	
	Groundnut	TMV-2,	First fortnight of August, Arid
			Regions of Anantapur
	Pearl millet	ICTP 8203 WCC-75	Red soils.
	Sunflower	MFSH-1, MFSH-8, MFSH-17, APSH-1L	Red soils and black soils
	Setaria	Lepakshi, Prasad, Srilakshmi	Black soils, deep red soils
September	Sunflower	MFSH-1, MFSH-8, MFSH-17,	Black soils .
		APSH-1J, Adarsha	
	Redgram	LRG-30, LRG-41	Red soils in regions receiving North- East Monsoon rainfall
	Sorghum	NTJ-1, NTJ-2, M-35-1, CSH-5	Red and Black soils
	Tobacco	Natu special, Sun cured natu	Black soils, deep red soils
October	Sorghum	M-35-1, CSH-7R, CSH-6R, CSH-13R, NTJ-1, NTJ-2, N-13, N-14	Black soils
	Coriander	CS-4, CS-6	Black soils

	Sunflower	Any hybrid	Black soils
November	Sorghum	Rabi varieties	Black soils
	Bengal gram	Annegiri, ICCV-2 (Swetha), ICCV-37(Kranthi), JG-11	Black soils
	Safflower	Manjira, Sagar muthyalu	Black soils
	Coriander	CS-6	Black soils

Table 10.4 Contingent crops for dryland regions of India

Onset of sowing rain	Crop	Varieties
	Dantiwada region of Gujarat	
July 15	Pearl millet	GHB 32, GHB 39
	Sorghum	CSH 5, CSH 6
	Castor	GAUCH-1, CAUCH-4
July 25	Sorghum	CSH-6, GJ-35
	Castor	GAUCH-1, GAUCH-4
	Clusterbean	Malosan, HG 75..
August 15	Castor	GAUCH-1, GAUCH-4
	Sorghum (fodder)	Malavan, S-1049
	Pearl millet (fodder)	
August 31	Sorghum (fodder)	
	Sesamum	Purva-1
	Pearl millet (fodder)	
September 15	Sorghum (fodder)	
	Sesamum	
	Maize (fodder)	
	Hissar region of Haryana	
Upto July 20	Pearl millet	HHB-50, HHB-45
August 15	Cluster bean	FS-227
October 15	Bengal gram	G-24, C-214
October 30	Mustard	RH-30
	Jodhpur region of Rajasthan	
July 20	Pearl millet	
	Greengram	
After July 20	Greengram	

Lecture No. 11 Evapotranspiration and measures to reduce evapotranspiration

11.1 Definition

Under dry land conditions soil moisture is the most limiting factor for crop production. It is lost as evaporation from soil surface and as transpiration from the plant surfaces. The combined loss of moisture through these two processes is known as evapotranspiration.

11.2 Methods to reduce evaporation

There are three principles of evaporation control under field conditions.

a. Decreasing the turbulent transfer of water vapour to the atmosphere by growing plants, raising wind breaks, straw mulches etc.,

b. Decreasing capillary conductivity by rapid drying of the surface soil layers.

c. Decreasing the capillary flow and moisture holding capacity of the surface soil layers.

For evaporation control, mostly mulches are used.

11.2.1 Mulches

Mulch is any covering material applied on the soil surface to reduce evaporation losses. This material may be grown and maintained in place, or any material grown and modified before placement or any material processed or manufactured and transported before placement.

Types of mulches

a. Soil mulch or dust mulch: soil mulch is a thin layer of loose soil surface that can be created by frequently stirring the soil with surface tillage implements like danthis, guntakas (blade harrows) etc., Soil mulch of surface 5-8 cm dry soil effectively reduces the evaporation losses by obstructing the raise of soil moisture through capillary action. The soil mulch also prevents deep cracks in soils (especially black soils) by reducing the direct action of atmosphere and hence evaporation is also reduced. The repeated intercultivations done in *rabi* crops even in the absence of weeds help in reducing evaporation losses. Among the different mulches soil mulch is the cheapest.

b. Straw and stubble mulch: Straw and other crop residues like stubbles, groundnut shells, cotton stalks etc; can be used as mulches on soil surface for moisture conservation. Straw mulches reduce both the amount of energy absorbed by the soil and its movement above the soil and hence reduce evaporation (Fig. 11.1) However, the availability of adequate crop residues is a problem for use as mulches.

Fig .11.1 Straw mulch in mango

c. Plastic mulches: Plastic mulches are very effective as mulches for evaporation control provided cost is not a limiting factor. The plastic mulches may be either white or black. Black plastic mulches will absorb the solar radiation and enhance the soil temperature for hastening the germination of winter crops like wheat; barley etc., White plastic mulches will reflect the incident radiation and reduce evaporation of soil moisture.

d. Chemical mulches: Chemicals like hexadeconol, a long chain alcohol when mixed with surface 5 mm of soil can reduce evaporation by about 40%. The surface layer of a treated soil dries out more rapidly than that of untreated soil, creating a diffusional layer to evaporation.

e. Vertical mulching: It is a technique wherein trenches of 40 cm wide, 15 cm deep are dug at 2 to 4 m interval across slope and filled with stubbles or organic wastes to a height of 10 cm above soil surface. Runoff is checked, collected in the shallow trenches and redistributed to adjoining soil layers and infiltration is increased in black soils.

f. Live mulching: Is the term used to describe the covering of soil surface through the plant canopy in intercropping system.

Eg. Sorghum + forage cowpea, sorghum + sword bean

g. Pebble mulch: Where small pebbles like stone are placed on the soil surface (Fig. 11.2). This mulching will be successful in dryland fruit tree culture. The pebbles placed on the basins of trees not only reduce evaporation but also facilitate infiltration of rain water into the basin.

Fig. 11.2 Pebble mulch in Mango

Mulching is more advantageous during *rabi*/summer months than in *kharif* season. Organic mulches particularly under receding soil moisture conditions increase crop growth by conserving soil moisture.

11.2.2 Effect of mulches on soil properties

1. **Soil structure**: Surface mulches reduce the impact of falling raindrops, thus reducing dispersion and sealing of soil pores leading to crust formation. Hence the soil structure is protected. The mulches also improve soil structure due to decomposition of mulch.

2. **Soil salinity**: Under dry land conditions due to limited precipitation, soluble salts move only to a limited depth and readily return to the surface as the soil water evaporates. Due to salt accumulation in surface layers the germination and seedling establishment may be adversely affected. Hence, mulches will reduce soil salinity problem by increasing infiltration and reducing evaporation.

3. **Soil water**: The soil moisture content is improved by induced infiltration, reduced evaporation and reduced transpiration by weeds. Surface mulches also obstruct the free exchange of water vapour from soil surface into the atmosphere and hence increase soil water content.

4. **Soil temperature**: The effects of mulches on soil temperature are highly variable and depend up on the type of mulch material. White or reflective type of plastic mulches generally decrease soil temperature, while black plastic mulches may increase soil temperature. Crop residues moderate temperature by decreasing it in summer and by increasing in winter season. This is due to combined effect of radiation interception and evaporative cooling. The sugarcane trash mulch will enhance the germination of sugarcane setts during summer by temperature reduction.

5. **Soil erosion**: The ease by which soil particles are moved by wind and water is related to size of soil particles and wind and water velocity. The particles of size greater than 0.84 mm in diameter are generally not eroded by wind but they are easily eroded by water. The mulches reduce the direct impact of falling raindrops on soil, there by preventing soil dispersion and consequent sealing of soil pores leading to reduced soil erosion.

11.3 Reducing losses due to transpiration

Nearly 99% of water absorbed by the plant is lost in transpiration. Hence transpiration reduction is needed for maintaining favorable water balance in the plants. Transpiration has become unavoidable evil as the stomata, which allow CO_2 exchange also allows water vapour transfer into the atmosphere.

There are four principles of transpiration control

a. By increasing leaf resistance to water vapour transfer by application of materials, which tend to close or cover stomata (ex: both stomatal closing and film forming type of antitranspirants).

b. By reducing amount of energy absorbed by leaf surface (Eg: leaf reflectants)

c. By reducing top growth of plants (Eg: Growth retardants)

d. By increasing air resistance to water vapour transfer by shelter belts/ wind breaks

The transpiration losses can be controlled by use of antitranspirants, use of wind breaks/shelter belts and efficient weed control

11.3.1. Anti-transpirants: Any material that is applied on transpiring plant surface for reducing water loss is called antitranspirants. The antitranspirants are also known as transpiration suppressants. The best anti transpirants reduce transpiration losses up to 30-40%. There are four types of anti transpirants.

a. Stomatal closing type: Transpiration mostly occurs through stomata on the leaf surface. Some fungicides like PMA (phenyl mercuric acetate) and herbicides like atrazine in low concentrations serve as anti transpirants by closing of stomata. PMA is known to inhibit mesophyll photosynthesis. Though the success was reported from glasshouse studies, their effectiveness under field conditions is limited.

b. Film forming type: The plastic and waxy materials, which form a thin film on the leaf surface, retard the escape of water due to formation of physical barrier. The success of these chemicals is limited since they also reduce photosynthesis. The desirable characteristics of film forming type of antitranspirants are: they should form a thin layer, they should be more resistant to the passage of water vapour than carbon dioxide and the film should maintain continuity and should not break. These film forming anti transpirants may be of either thin film or thick film.

Thin film forming type: Hexadeconol

Thick film forming type: Mobileaf, Polythene S-60

c. Leaf reflectant type: These are the white materials, which form a coating on the leaves and increase leaf reflectance (albedo). By reflecting the radiation they reduce leaf temperatures and vapour pressure gradient from leaf to atmosphere and hence reduces transpiration. About 5% of kaolin spray reduces the leaf temperature by 3-4°C and decrease in transpiration by 22 to 28 per cent. Celite and hydrated lime are also used as reflectant type of anti transpirants.

d. Growth retardant type: These chemicals reduce shoot growth and increase root growth and thus enable the plants to reduce transpiring surface and resist drought conditions. They increase root/shoot ratio.

Eg : Cycocel – (2-chloroethyl) Trimethyl ammonium chloride (CCC), Phosphon–D, Maleic Hydrazide (MH)

Antitranspirants generally reduce photosynthesis. Therefore, their use is limited to save the crop from death under severe moisture stress. If crop survives, it can utilise the rainfall that is received subsequently. Antitranspirants are also useful for reducing the transplantation shock of nursery plants. They have some practical use in nurseries and horticultural crops. Waxy materials are used for reducing post harvest shrinkage of fruits.

11.3.2. Use of wind breaks and shelterbelts: Wind breaks are any structures that obstruct wind flow and reduce wind speed while shelterbelts are rows of trees planted for protection of crops against wind. The direction from which wind is blowing is called windward side and direction to which wind is blowing is called leeward side. Shelterbelts are planted across the direction of wind. They do not obstruct the wind flow completely. Depending upon their porosity, certain amount of wind passes through the shelterbelts while the rest deflects and crosses over the shelterbelts (Fig. 11.4). It thus reduces wind speed without causing turbulence. The protection offered by the shelterbelts is dependent on the height of central tree row in the shelterbelts. Generally, shelterbelts give protection from desiccating winds to the extent of 5 to 10 times their height on windward side and up to 30 times on leeward side. Due to reduction in wind speed, evaporation losses are reduced and more water is available for plants. The beneficial effect of shelterbelts are seen more clearly in drought years. In addition, shelterbelts reduce wind erosion.

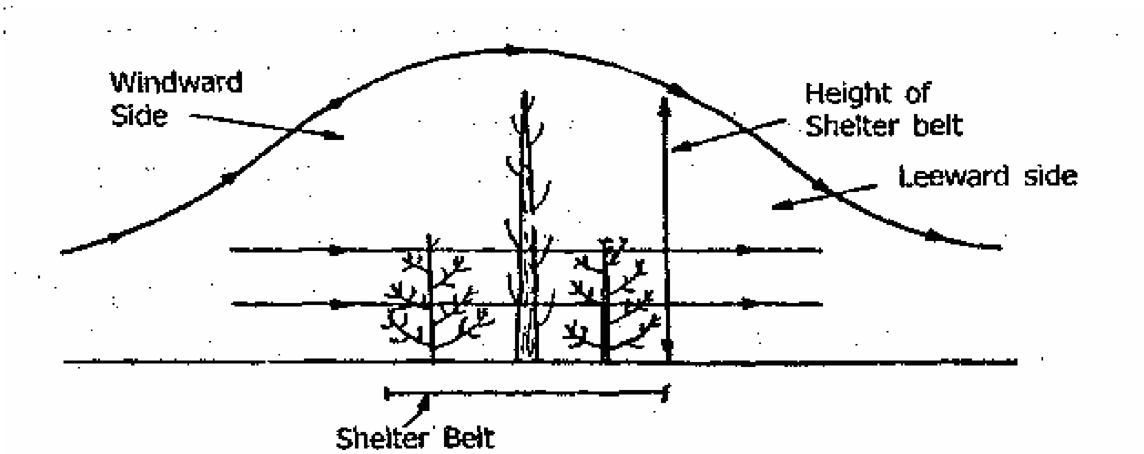


Fig 11.4 Wind Deflection due to shelterbelts

11.3.4 Effective weed control: Weeds transpire frequently greater amount of water per unit of dry matter production than the crop plants. Therefore controlling weeds especially at early stages of crop growth will be most effective means of increasing the amount of water available for crops. This is the most useful method to reduce transpiration losses.

Lecture No. 12 Watershed management – objectives and approaches of watershed management

12.1 Introduction

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

12.2 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 (Fig.12.1). 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.

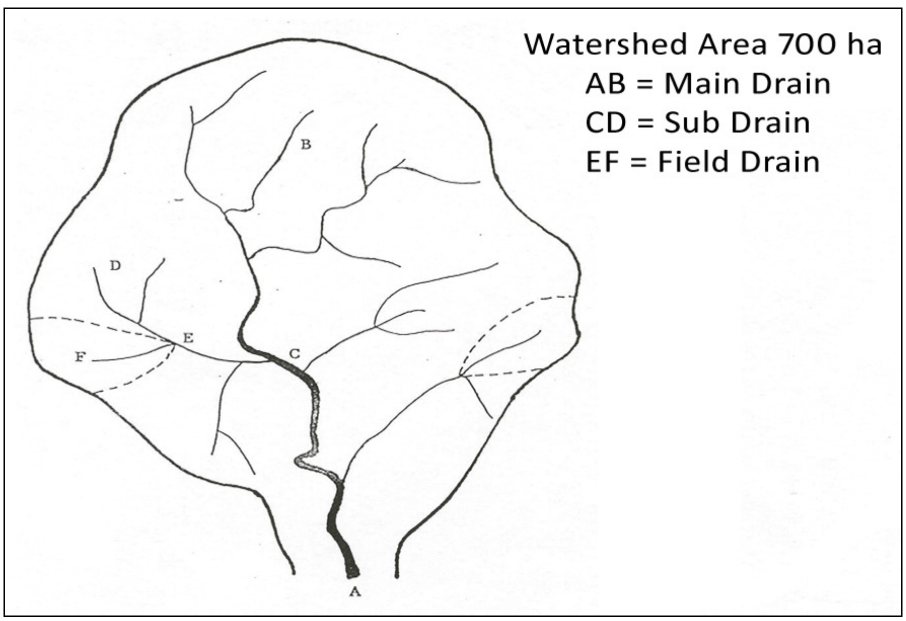


Fig. 12.1 watershed with main and sub drains

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.

12.3 Principles of watershed management

- Utilizing the land based on its capability
- Protecting the fertile top soil

- Minimizing the silting up of the reservoirs and lower fertile lands
- Protecting vegetative cover throughout the year
- *Insitu* conservation of rain water
- Safe diversion of surface runoff to storage structures through grassed water ways
- Stabilization of gullies and construction of check dams for increasing ground water recharge.
- Increasing cropping intensity through inter and sequence cropping.
- Alternate land use systems for efficient use of marginal lands
- Water harvesting for supplemental irrigation
- Ensuring sustainability of the ecosystem
- Maximizing farm income through agricultural related activities such as dairy poultry, sheep, and goat farming
- Improving infrastructural facilities for storage transport and agricultural marketing
- Setting up of small scale agro industries and
- Improving socio-economic status of farmers.

12.4 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

- Recognition of watershed as a unit for development and efficient use of land according to land capabilities
- Flood control through small multipurpose reservoirs and other water storage structures at the headwater of streams and problem areas.
- Adequate water supply for domestic, agricultural and industrial needs

- Reduction of organic, inorganic and soil pollution
- Efficient use of natural resources for improving agriculture and allied occupations so as to improve socio- economic conditions of the local residents and
- 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

12.5 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

Lecture No. 13 Components of watershed management programme and land capability classification

13.1 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

13.1.1. 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:

Permanent treatments (Hardware treatments)

Semi permanent treatments (medium software treatments) and

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.

Bunds: 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 and for soils having crust like ,chalka soils of Telangana region of A.P.

Terraces: Bench terracing: suitable for soils having slopes 16 to 33%. Bench terraces reduce both slope length and degree of slope. At Ootacamund erosion rate decreased from 39 t/ha to less than 1.0 t/ha on 25% sloping land by bench terracing.

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.

i. **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.

ii. **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.

iii. **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.

iv. **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.

13.2. Water harvesting: The water harvesting structures and the use of harvested water for life saving irrigation in watershed areas is discussed in detail in lecture No .15

13.3 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

13.4 Alternate land use systems: Alternate land use systems are discussed separately in lecture No.16

13.5 Land use classification (land capability classification)

Land capability classification is grouping of soils into different classes according to their capability for intensive use and treatments required for sustained use. It emphasizes the need for using the land only for what it is suited best to realize optimum returns, without land degradation. Land capability classification system developed by USDA is useful for Agriculture. Eight land capability classes are recognized and designated by Roman numericals from I to VIII. The Roman numericals indicates increasing limitations and fewer choices for practical field crop use.

Land capability classes from I to IV are suitable for arable crop production

Land capability classes from V to VIII are suitable for alternate land use systems

CLASS I: This group of soils has few limitations on their use. They are deep (> 90cm), well drained and nearly levelled. They are fertile or responsive to fertilizer application. There is no limitation on the type of crops grown. A variety of crops can be grown intensively with recommended management practices. They are suitable for intensive cultivation. This group of soils is represented by light green colour in land use maps

CLASS II: Soils have moderate limitations such as gentle slope, moderate erosion problem, inadequate depth (22.5–45cm), slight salinity and alkalinity and relatively restricted drainage. Less intensive cropping systems must be followed. Simple management practices such as contour cultivation will maintain the soil for crop production. They are represented by yellow colour in land use maps.

CLASS III: Soils have moderate to severe limitations. The soil erosion, shallow water permeability, low moisture retentively, moderate salinity and low fertility are the limitations for their use. Soils can be used for crop production with special conservation practices like terracing. Smothering crops such as legumes are more ideal than row crops. They are represented by red colour in land capability maps.

CLASS IV: These soils will have very severe limitations that reduce the choice of crops. Steep slope, severe erosion, shallow soil depth, salinity or alkalinity restricts their use for profitable crop production. These lands should be used for close growing crops or grasses with special soil conservation practices.

CLASS V: These soils generally not suitable for grain crops due to limitations such as rocky soil, faded areas with no drainage facilities. Pastures can be improved on this class of land.

CLASS VI: These soils are suitable for growing grasses and forest trees. Limitations are same as those for class V but they are more rigid. Their use may be restricted to woodland or wild life.

CLASS VII: These have severe limitations even for growing grass and forest trees. They are steep soils of extremely shallow depth, used for woodlands and wild life.

CLASS VIII: Not suitable for forest trees and grasslands as they are steep, rough stony mountains. Land use is restricted to recreation, wild life etc.,

Capability classes can be sub divided into sub classes with in each class based on special limitations. They are designated by adding small letter c, e, s or w to roman numerical.

c : shows that chief limitation is climate, low rainfall, too cold or too dry (very high or very low temperature)

e : chief limitation is soil erosion

s : main limitation is soil character like depth (shallow depth, stony, salinity, rocky)

w : soil wetness, excess water in or on soil interferes the plant growth

Lecture No. 14 Soil and water conservation measures in watershed areas

14.1 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.

14.1.1 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.

14.1.2 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

14.1.3 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 (Fig 14.1). Broad bed furrow has many advantages over other methods.

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

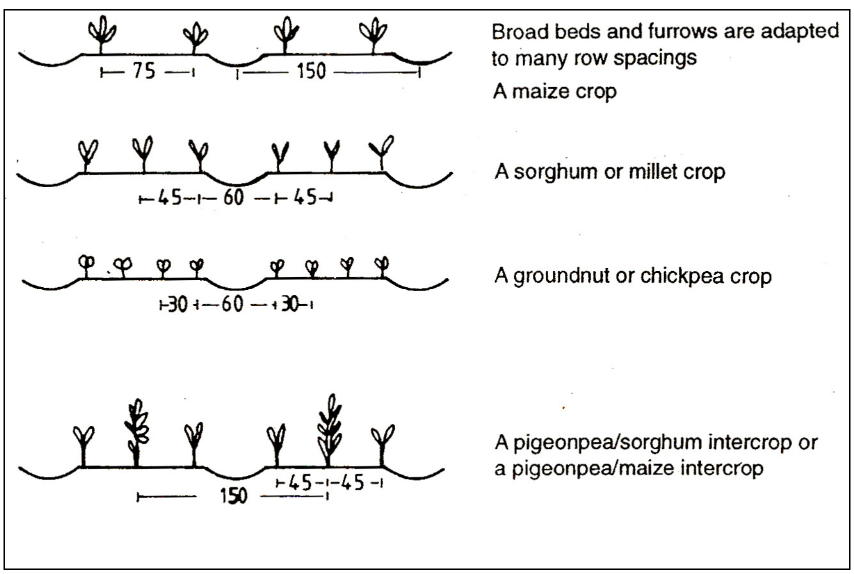


Fig. 14.1 Alternate crop and row arrangement on broad beds

14.1.4 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

14.1.5 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 (Fig 14.2).

Fig 14.2 Compartmental bunding

14.1.6 Scooping

Scooping the soil surface to form small depressions or basins help in retaining rain water on the surface for longer periods (Fig 14.3). 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.

Fig. 14.2 Scoops for insitu moisture conservation

14.1.7 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.

14.1.8 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 leveled 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.

14.2 Mechanical / Engineering measures of soil conservation

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:

- Contour bunding
- Graded bunding
- Bench terracing
- Gully control / plugging
- Vegetative barriers etc.

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.

14.2.1 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 (Fig. 14.4).

Fig 14.4 Contour bunding

14.2.2 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) as in case of Bellary region of Karnataka. 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.

14.2.3 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 (Fig. 14.5).

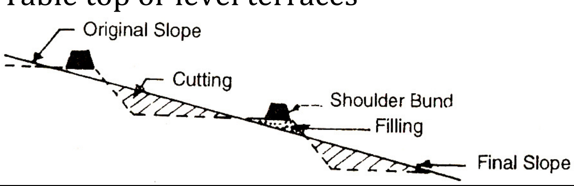
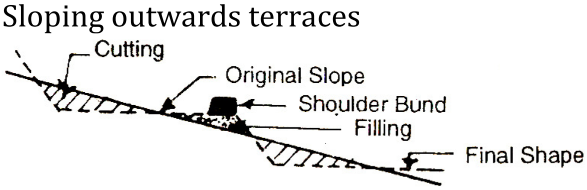
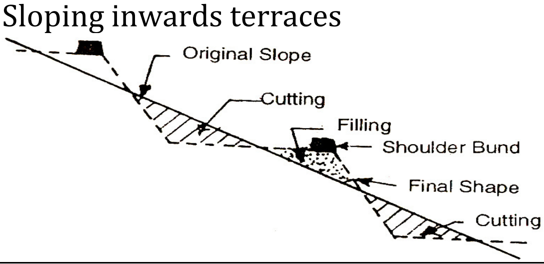
Type of bench terrace	**Suitability**
Table top or level terraces 	Suitable for medium rainfall areas (750mm) with even distribution and highly permeable deep soils.
Sloping outwards terraces 	Constructed in low rainfall areas (<750 mm) with permeable soils of medium depth.
Sloping inwards terraces 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

Fig 14.5 Types of bench terraces

14.2.4 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 (Fig. 14.6 and 14.7).

Fig. 14.6 Concrete check dam for gully control

Fig. 14.7 Loose boulder check dam for gully erosion control

14.2.5 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.

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. Objectives of grassed waterways

1. To provide drainage to agricultural lands
2. To convert unstable channels or gullies into stable channels by providing grass cover
3. 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.

14.3 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 (Fig. 14.8 and 14.9). Tree species suitable are *Pinus patula, Pinus kesia, Acacia nilotica, Eucalyptus camaldulensis* etc.

Fig. 14.8 Regenerating degraded land with contour trenching in Anantapur, A.P

Fig . 14. 9 Continuous contour trenching

14.4 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 67up soil fertility by fixing atmospheric N in root nodules. Grasses have several uses in soil conservation like:

- Stabilizing the surfaces of water ways, contour bunds and front faces of bench terraces
- Stabilizing the gully slopes and sides
- Preventing wind erosion

The desirable characters of grasses for soil conservation are:

- Should be perennial
- Drought resistant
- Rhizomniferous
- 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, is best for A.P.

Lecture No. 15 Water harvesting and life saving irrigation

15.1 Introduction

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.

15.2 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.

15.2.1 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, house-holds, 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.

15.2.3 Methods of Water Harvesting

The different methods of water harvesting that are followed in arid and semiarid regions are discussed separately.

15.2.3.1 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 m^3 to 15000 m^{3-} .*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.

15.2.3.2 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.15.1)

Fig. 15.1 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 m^3 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 10 m x 10 m x 2.5 m to 15 m x 15 m x 3.5 m. 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.15.2 to 15.4) In alluvial sandy loam to loamy sand soils of Gujarat and red sandy loams soils of Bangalore, a soil + cement (8 : 1) mixture is" the best lining material. At

Fig. 15.2 Farm Pond Lined with Kadapa Slabs

Fig .15.3 Farm Pond lined with Cement Bricks

Fig. 15.4 Farm Pond Lined with Fire Bricks

Anantapur (A.P.), soil without sieving and cement in 6:1 ratio (Fig. 15.5) is very effective and cheap lining material for red sandy loam soils. In laterite silty clay loam soils of Ooty, medium black soils of Kota, bitumen was effective. Water can be stored for two months in deep heavy soils with out lining at Nandyal (AP). Clay soils linings are generally the most economical. Evaporation losses can be reduced in farm ponds especially in arid regions by rubber or plastic floats. White plastic sheet is economical and easily available. Farm pond technology is economically viable. Studies undertaken in the Jhanwar model watershed in Rajasthan showed that water harvesting in a farm pond of size 271 m^3 and utilizing the water for supplemental irrigation is economically viable.

Fig: 15.5 Farm Pond lined with soil + cement (6:1 ratio)

15.3 Supplemental irrigation / life saving irrigation:

The runoff collected from different water storage structures is of immense use for protecting the dryland crops from soil moisture stress during prolonged dry spells. Supplemental or life saving or protective irrigation is given to sustain the dry land crop during the drought periods and take the advantage of subsequent rains. In dry areas, water, not land is the most limiting resource for crop production. Maximizing the water productivity but not the yield per unit land is the better strategy for dry farming areas. Supplemental irrigation is a highly efficient practice for increasing productively of crops in arid regions. The response to supplemental irrigation varies with crops, time of irrigation, depth of irrigation, method of water application and fertilizer application.

a) Quantity of irrigation water: Crops differ in responding to amount of irrigation water by supplemented irrigation during dry spell. Groundnut responds to 10 mm of irrigation through sprinkler on affisols during pod development stage. The benefit of supplemental irrigation lost for one week. Cotton needs a minimum of 30 mm of water to respond to irrigation applied either by sprinkler or drip irrigation system on vertisols. Chickpea similarly need 30 to 40 mm of supplemental irrigation applied as drip or sprinkler irrigation during flowering. Pigeonpea responds to 20 mm irrigation water applied at pod development stage with drip irrigation. Irrigation can be provided near the row, covering about 20% of the cropped area, leaving 80% of interrow zone. Pot watering, applying small quantity of water (around 250 ml) manually to each hill, is highly useful either for sowing or for transplanting in widely spaced crops like cotton, Redgram, castor, tomato, tobacco etc. Similarly, pot watering to protect the seedlings during early crop growth stage is highly useful. The amount of water, if calculated over the entire area, works out less than 5 mm. For example, pot watering cotton seedlings at 250 ml/ hill works out 5,000 1/ha which works out to 5 mm. Productivity of harvested water can be increased by applying small quantity of water to large areas than heavy irrigation to small area. If rains occur immediately after irrigation, there will be no impact of irrigation and in black soil, it may reduce yield.

b) Time of irrigation: Unlike in irrigated agriculture, the critical stage concept does not suit well, as dry spell may reduce the growth and yield of crop at any stage. Vegetative stage is considered as, non-critical stage in irrigated agriculture but in arid regions, dry spell during vegetative stage prolongs the crop duration which may ultimately result in crop failure due to end season drought. Death of seedlings also cause reduction in yield due to dry spell in vegetative stage, therefore, the strategy for getting successful crop is providing small quality of water, if available, at any stage if the dry spell is more than 10 days in light soils and 15 days in heavy soils.

c) Method of irrigation: Surface methods of irrigation like check basin, basin, and furrow methods are not suitable for supplemental irrigation, mainly for three reasons : the rainfed lands are uneven, conveyance losses may go up to 30% and limited amount of water available for irrigation. Drip and sprinkler irrigations are more suitable because small amount of water can be delivered, even on uneven soils with out conveyances losses (Fig15.6). Subsurface drip irrigation is very efficient for providing supplemental irrigation. The main drawback of micro-irrigation system is high initial cost of the system. Pot watering is another efficient method being used by the farmers for transplanting crops like tobacco, chilly, tomato etc.,

Fig: 15.6 Supplemental irrigation to tamarind by drip irrigation

d) Economics of water harvesting: Water harvesting and use of water for sowing and supplemental irrigation increase the productivity of wheat and onion in mountainous watershed in Himachal Pradesh. The benefit-cost ratio ranges from 0.41 to 1.33 for water harvesting structures of different sizes with an estimated life of 25 and 40 years respectively.

15.4 watershed Problems

a) Physical problems: Steep slopes, bad lands, weak geological formations etc., can be found by observation of the existing maps. Problems such as heavy and intense rainfall, excessive runoff and strong winds can be identified from the weather and hydrological data.

b) Resource use problems: Problems such as shifting cultivation, forest destruction, fire, over grazing, poor road construction and uncontrolled mining should be identified.

c) End problems: The final effects of watershed degradation i.e. soil erosion, land slides, heavy sedimentation, water pollution, floods and droughts must be identified as quickly as possible. By analyzing the information like history, frequency and extent of these problems can be determined.

d) Socio economic and other problems: Serious sicio economic problems can be major obstacles in carrying out watershed work. Any serious problem should be identified at the beginning of the stage. These may include land tenure, poverty, lack of education, low acceptance of innovations, seasonal shortage of labour etc.,

Lecture No. 16 Alternate land use systems – agroforestry systems

16.1 Introduction

Land use planning is a scientific evaluation of land area in question, study of existing land use and their capabilities, suggesting alternative uses and predict the possible impact to arrive at sound decisions for sustained land use. Land use is the application of human control of natural ecosystems in a relatively systematic manner in order to derive benefits from it.

Soils of the SAT regions are poor in fertility, structurally degraded, undulating in topography and mostly shallow in depth. Since land resources vary spatially, all drylands are not suitable for arable farming. Soils belonging to land capability classes IV and above are not very suitable to arable farming due to certain inherent limitations. Sustainable dryland agriculture demands land capability based alternate land use technologies and management strategies.

16.2 Alternate land use systems

A pattern of land use that is different from the existing or the conventional can be described as an alternative land use system. The term alternate land use is applicable to all classes of land to generate assured income with minimum risk through efficient use of available resources. The advantages of alternative land use systems are

- Optimising resource use by enhancing biological productivity and profitability,
- Conserving and enhancing the quality of resource base,
- Integrating crops (arable and pastoral) and livestock,
- Making agriculture less dependent on off-farm inputs,
- Generating employment potential, and
- Improving overall quality of farm life.

Commonly known alternate land use systems are agroforestry (agrisilviculture, silvipasture, agrihorticulture and alley cropping), tree farming and ley farming. The possible alternate land uses as per land capability classification and rainfall is furnished in Fig.16.1

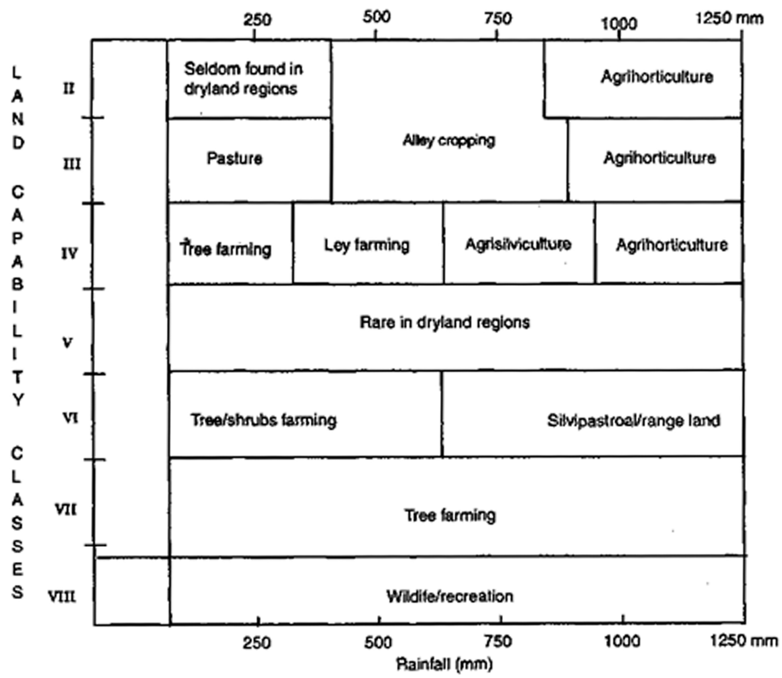


Fig. 16.1 Possible alternate land uses as influenced by resource (LCC and mean annual rainfall) capability (Katyal *et al.,* 1994).

16.3 Agroforestry

Agroforestry may be defined as an integrated self sustained land management system, which involves deliberate introduction/retention of woody components with agricultural crops including pasture/livestock, simultaneously or sequentially on the same unit of land, meeting the ecological and socio-economic needs of people. It is also defined as a collective name of land use systems and technologies where woody perennials are deliberately used from the same land management units as agricultural crops and/or animals in some form of special arrangement of temporal sequence.

In agroforestry systems, there is both ecological and economic interaction between different components. An agroforestry system is more acceptable than tree farming alone, since the intercropped annuals regulate income when the trees are too young to yield beneficial produce.

The different agroforestry systems are:

16.3.1 Agri-silviculture

This alternate land use system combines perennial arboreals with annual arable crops. It integrate crops and trees. Tree component gives fodder, fuel or timber, including green leaf manure. It is ideal for class IV soils of drylands with annual rainfall around 750 mm.

Eg: *Leucaena leucocephala* + Sorghum

Sesbania aegyptica + Pulses

16.3.2 Silvi-pastoral system

This system is primarily meant for augmenting the scarce fodder supply. This system integrate pasture and/or animals with trees (Fig.16.2).

Eg: Acacia + Cenchrus + Stylosanthus

Sissoo + Cenchrus + Stylosanthus

Fig. 16.2 Silvipasture system

16.3.3 Agri-silvi-pastoral system

This system integrate crop, pasture and/or animals with trees. Woody perennials, preferably of fodder value, are introduced deliberately. Such systems can be used for food production and soil conservation besides providing fodder and fuel.

16.3.4 Agri - horticultural system

It is one form of agroforestry in which the tree component is fruit tree. It is also called as food-cum-fruit system in which short duration arable crops are raised in the interspaces of fruit trees. Some of the fruit trees that can be considered are guava, pomogranate, custard apple, sapota and mango. Pulses are the important arable crops for this system (Fig.16.3). However, depending on the requirements, crops like sorghum and pearl millet can be grown in the interspaces of fruit trees.

Fig. 16. 3 Mango + groundnut

16.3.5 Horti - pastoral system

Horti-pastoral system is an agroforestry system involving integration of fruit trees with pasture. Guava, custard apple and ber suits well in an horti pastural system with grasses like *Cenchrus ciliaris* (anjan), *Panicum antidotale* (blue panic), *Dicanthicum annulatum* (marvel) and *Chloris gayana* (rhodes) and legumes like *Stylosanthus hamata* (stylo) *Stylosanthus scarba* (stylo) and *Macroptilum atropurpureum* (siratro) (Fig.16.4).

Fig 16.4 Guava + *Cenchrus ciliaris*

16.3.6 Alley cropping

Food crops are grown in alleys formed by hedge rows of trees or shrubs in arable lands. It is also known as **hedgerow intercropping or avenue cropping.** Hedgerows are cut back at about one meter height at planting and kept pruned during cropping to prevent shading and to reduce competition with food crops. It is recommended for humid tropics, primarily as an alternative to shifting cultivation. In semiarid regions of India, alley cropping provide fodder during dry period since mulching the crop with hedgerow prunings usually does not contribute to increased crop production. Advantages of alley cropping are:

- Provision of green fodder during lean period of the year
- Higher total biomass production per unit area than arable crops alone
- Efficient use of off-season precipitation in the absence of a crop
- Additional employment during off-season
- It serves as a barrier to surface runoff leading to soil and water conservation.

Based on the objectives, three types of alley systems are recognised.

- Forage-alley cropping,
- Forage-cum-mulch system, and
- Forage-cum-pole system.

a) Forage alley cropping system: In this system, both yield of crop and forage assume importance. The tree species suitable for hedge rows are *Leucaena leucocephala, Colliendra and Sesbania*. .Pigeon pea or castor crops are suitable for growing in the alleys of Leucaena.

b) Forage-cum-mulch system: In this system, hedgerows are used for both forage and mulch. Loppings are used for mulching during the crop season and used as fodder during off season. Substantial increase in crop yields of sorghum, groundnut, greengram and blackgram have been observed at several places.

c) Forage-cum-pole system: *Leucaena* alleys are established at 5 m intervals along the contours. Hedgerows are established by direct seeding and topped every two months at 1.0 m height during crop season and every four months during the off season. A *Leucaena* plant for every 2 m along hedgerows is allowed to grow into a pole.

16.3.7 Tree farming

Trees can flourish and yield abundantly where arable crops are not profitable. Farmers of drylands are inclined to tree farming because of labour cost, scarcity at peak periods of farm operations and frequent crop failure due to drought. A number of multipurpose tree systems (MPTS) have been tested for their suitability and profitability under different situations.

Trees for areas where annual rainfall less than 500 mm: *Acacia nilotica, Acacia aneura, Acacia tortilis, Acacia albida, Prosopis cineraria, Prosopis juliflora, Pithecallobium dulce, Leucaena leucocephala,. Tamarindus indica etc.,*

Trees for areas where annual rainfall less than 500 mm: *Acacia nilotica, Acacia ferruginea, Albizzia lebbek, Azadirachta indica, Casuarina equisetifolia, Cassia sturti, Dalbergia sissoo etc.,*

16.3.8 Timber-cum-fibre system (TIMFIB)

It involves growing trees and perennial fibre crops together on the same piece of land.Subabul intercropping with agave appears to be more remunerative at Bijapur area of Karnataka..

16.4 Ley farming

This system involves rotation of legume forages with cereals. A rotation system which includes pasture (ley) for grazing and conservation is called **alternate** husbandry or mixed farming. It is a low risk system for drylands. Inclusion of *Stylosanthes hamata* (legume fodder) in rotation improved soil fertility besides increasing sorghum yield.

ABBREVIATIONS

AICRPDA	:	All India Coordinated Research Project on Dryland Agriculture, Hyderabad
AISSLUP	:	All India Soil Survey and Land Use Planning, New Delhi
CAZRI	:	Central Arid Zone Research Institute, Jodhpur
CGWB	:	Central Ground Water Board, New Delhi
CIAE	:	Central Institute of Agricultural Engineering, Bhopal
CIDA	:	Canadian International Development Agency
CRIDA	:	Central Research Institute for Dryland Agriculture, Hyderabad
CSWCRTI	:	Central Soil and Water Conservation Research and Training Institute, Dehradun
DDP	:	Desert Development Programme
EGP	:	Effective Growing Period
GIS	:	Geographical Information System
ICARDA	:	International Centre for Agriculture Research on Dry Areas, Aleppo, Syria
ICRAF	:	International Centre for Research on Agroforestry, Nairobi, Kenya
ICRISAT	:	International Crops Research Institute for Semi-Arid Tropics, Hyderabad
IGFRI	:	Indian Grassland and Fodder Research Institute, Jhansi
IWDP	:	Integrated Watershed Development Project
LCC	:	Land Capability Class
NBSS & LUP	:	National Bureau of Soil Survey and Land Use Planning, Nagpur
NRCAF	:	National Research Centre for Agroforestry, Jhansi
NRSA	:	National Remote Sensing Agency, Hyderabad
NWDB	:	National Wasteland Development Board, New Delhi
NWDPRA	:	National Watershed Development Programme for Rainfed Areas
UNDP	:	United Nations Development programme
USDA	:	United States Department of Agriculture

References

Arnon I, 1992. Agriculture in Drylands- Principles and Practices, I, Elsevier Pub. Co., London

Dhruva Narayana V V, Sastry G S and Patnaiak V S, 1999. Watershed Management in India, ICAR, New Delhi

Gupta U S, 1975. Physiological Aspects of Dryland Farming, Oxford and IBH Publishers Co. Ltd., New Delhi

ICAR, 1970. A new Technology for Dryland Farming, ICAR Publication, New Delhi

Mohd Shahid and Mohd Raza, 1987. Dryland Agriculture in India, Rewa Publications, Jaipur

Murthy J V S, 1994. Watershed management in India, Willey Eastern Publishers, New Delhi

Sharma B L, 1991. Dryland Farming- Perspectives and Prospects, Daya Publishing House, New Delhi

Somani L L, Vittal K P R and Venkateswarlu B, 1992. Dryland Agriculture – Status Research in India, Scientific Pub., Jodhpur

Yellamanda Reddy T and Sankar Reddy G H, 1995. Principles of Agronomy, Kalyani Publishers, Ludhiana