SYLLABUS

Rainfed Agriculture and Watershed Management [ASAG2211]

Theory Class course outlines:

Chapter No.	Topic
1	Introduction, types and its importance
2	History of rainfed agriculture & watershed in India
3	Problems and prospects of rainfed agriculture in India
4	Soil and climatic conditions prevalent in rainfed areas
5	Drought: introduction and its types/classification of drought
6	Effects of drought on physio- morphological characteristics of the plants
7	Mechanism of crop adaptations under moisture deficit condition
8	Strategies for drought management
9	Water harvesting: importance and its techniques, Efficient utilization of water through soil and crop management practices and Management of crops in rainfed areas
10	Contingent crop planning for aberrant weather conditions
11	Watershed management: introduction, Concept and its objective
12	Principles and components of watershed management
13	Factors affecting watershed management

Lecture- 1

Rainfed farming-introduction and definition and importance

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 itself. Growing of crops entirely under rainfed conditions is known as dryland agriculture.

Total geographical area of India is 328.12mha. In this 175 mha of land is degrading every year due to erosions (soil, water & wind). Among the total geographical area dryland area is 85 mha. Total net cultivated area in India is 143mha.

1.1 DEFINITIONS:

Depending on the amount of rainfall received, dryland agriculture can be grouped into three categories:

Dry farming: It 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.

Dryland farming: 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 **semiarid 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.

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.

1.2 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:

- About 70% of rural population lives in dry farming areas and their livelihood depend on success or failure of the crops
- Dryland Agriculture plays a distinct role in Indian Agriculture occupying 60% of cultivated area and supports 40% of human population and 60 % livestock population.
- 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.
- By the end of the 20th 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.
- 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.
- 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.
- 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.
- 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.

Lecture 2

HISTORY OF RAINFED AGRICULTURE

A. Pre-Independence period:

From time immemorial, the chief form of agriculture in the dryland tracts of India was cultivation of drought resistant crops viz., millets for food and fodder. It used to be a gamble with rainfall. During good rainfall years, the hardships of farmers seem to have been mitigated, as surplus grain and fodder were available. But, as water is the most important single factor of crop production, the inadequacy and extremely uncertainty of rainfall often caused partial or complete failure of crops leading to periodic food scarcities and famines.

Drought was a frequent phenomenon. These factors made the economic life of the dryland cultivator extremely difficult and insecure. To address these issues, the Government of India appointed the First Famine Commission in 1880. The Commission recommended creation of protective irrigation projects in the dry tracts.

The Government of India constituted Royal Commission on Agriculture in 1928. The Commission revived the Department of Agriculture of the Government of India, and simultaneously founded the Departments of Agriculture in all the provinces. The Departments concentrated more on the best performing crops, but neglected millets and other crops of the rainfed areas. A few years of study at Manjari Farm led to the conclusion that the problem of cultivation of dryland crops was vast in extent and complex in nature. It required simultaneous in-depth research on different aspects such as conservation/collection of excess rainwater, soil characteristics and water requirements of crop plant.

The dry spells extended from 3 to more than 8 weeks during the rainy seasons. It was thus felt that for good crop production, conservation of soil moisture and minimization of surface evaporation comprised the most suitable interventions. Soil Loss and Moisture Conservation. In the Deccan Plateau, under normal cultivation, soil slope, low rate of infiltration and high intensity rainfall causes runoff. It was between 12 and 20 per cent with a concurrent upper soil loss of 10-14 t/ha/year due to erosion. During the rainy season, in the cropped fields, about 10 per cent of the rainfall was lost as runoff from black, and about 25 per cent from red soils. It was realized that the land needed some kind of vegetal cover to minimize the runoff and soil loss. Kharif (rainy season) crops such as pearlmillet (Pennisetum glaucum) and pigeonpea (Cajanus cajan) provided cover to the soil, thus resulting in considerable reduction in runoff and soil loss. Deep ploughing, soil stirring and mulching helped to conserve soil moisture. Fallowing was also useful. Good yields were realized from sowing in wider rows with low seed rates of selected crop varieties.

The practices, thus developed were given for different dry tracts in the form of principles of dry farming applicable to Indian conditions and suggestions were made for future line of research and extension. The packages of practices were popularly known as Bombay, Madras and Hyderabad Dry Farming Practices.

The recommended practices constituted the following:

• Constructing contour bunds as the basic and essential treatment

• Occasional deep ploughing of lands, once in 3 years

• Repeated shallow cultivation of soils (4 to 5 inter-cultivations) to remove weed and conserve moisture during the rainy season, particularly for rabi (postrainy) season sorghum (Sorghum bicolor)

• Adding moderate quantities of Farm Yard Manure to maintain the fertility and physical conditions of eroded soil, • sowing in wider rows (45 cm row spacing for sorghum) with lower seed rate

• Adopting mixed cropping / crop rotations wherever possible

• Fallowing a part of the holding every year.

Unfortunately, the returns from the adoption of these technologies resulted in lower yields (40 to 100 kg grain/ha) probably due to: discouragement to use inputs and nonavailability of proper biological material.

1. 1923 Establishing Dryland Research Station at Manjri (Pune) by Tamhane
2. 1972 Establishment of ICRISAT
3. 1985 Birth of Central Research Institute for Dryland Agriculture at Hyderabad
4. 1970 Research Centres established under AICRPDA in 23 locations
5. 1986 Launching of NWDPRA programmes by Government of India in 15 states.
6. The average annual rainfall of India is 1192 mm where as in Andhra Pradesh it is 890 mm.

Thus up to independence, the dryland agricultural research and development made no significant progress.

B. Post-Independence period:

Even after independence, vulnerability of dryland agriculture to droughts continued to haunt the country with ever increasing food shortages. The dryland research was also confined to long duration crops. Hence efforts were intensified to improve productivity and stability from rainfed areas. Another programme on 'Soil Conservation in the Catchments of River Valley Projects' was launched in 1962. It was later realized that this project focussed more on prevention of siltation of reservoirs and controlling floods, and gave secondary importance to agronomic aspects (Randhawa, 1983). In spite of development of major and minor irrigation projects and so also improvement in the availability of inputs like seeds, fertilizers, electricity and the like since India's independence, food shortages continued, and gradually food grain imports reached 10 million tonnes by 1966. At this juncture, with international collaboration, Indian agricultural scientists developed high yielding varieties / hybrids of major crops like wheat (Triticum aestivum), rice (Oryza sativa), maize (Zea mays), sorghum (Sorghum bicolor) and pearlmillet (Pennisetum typhoids) were introduced to the farmers during the period from early to late sixties.

C. Green Revolution

Keeping in view these continuing problems, the ICAR formulated an exhaustive programme on dryland agricultural research. Thus, the All India Coordinated Research Project for Dryland Agriculture (AICRPDA) was launched in 1970 with the support from Canadian International Development Agency through an instrument of bilateral collaboration signed between the Governments of India and Canada.

The Consultative Group on International Agricultural Research had established the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) at Hyderabad in 1972. The Krishi Vigyana Kendras (KVKs) were initiated in 1974 to demonstrate proven technologies in farmers' fields in most of the districts. The dryland agricultural research was further strengthened with the establishment of the All India Coordinated Research Project on Agro-meteorology (AICRPAM) in 1983 at Hyderabad with 12 Cooperating Centres (now 25). The modest beginning of AICRPDA resulted into establishment of a full-fledged research organization – the Central Research Institute for Dryland Agriculture (CRIDA) at Hyderabad in 1985.

The main purpose of this institute was to focus on lead research in dryland agriculture, leaving location specific problems and their solutions to AICRPDA and AICRPAM. The present mandate of CRIDA is (Anon., 2005a):

1. To undertake basic and applied research that will contribute to the development of strategies for sustainable farming systems in the rainfed areas,
2. To act as a repository of information on rainfed agriculture in the countr
3. To provide leadership and co-ordinate network research with state agricultural universities for generating location-specific technologies for rainfed areas
4. To act as a center for training in research methodologies in the fields basic to management of rainfed-farming systems
5. To collaborate with relevant national and international agencies in achieving the above objectives, and
6. To provide consultancy. In order to reduce the regional imbalances in agriculture, the ICAR set up the National Agricultural Research Project in 1987 to build up infrastructure and to strengthen the zonal research stations under SAUs for conducting location specific research.
7. The impact of accelerated growth rate in agricultural production did not last very long. Almost since the 1990s, there has been a stagnation or decline in the productivity and production of many crops in the country.

In other words, rainfed agriculture is synonymous to non-irrigated agriculture. It includes rainfed wetlands (N.E. status) as well as rainfed/drylands. Drylands are therefore part of rainfed lands.

Lecture 3

PROBLEMS OF CROP PRODUCTION IN DRYLANDS

The land degradation in rainfed areas has resulted from climatic variations and unplanned over-exploitation of natural resources by human activities, and increasing pressure of human and livestock population. It has become unavoidable to cultivate even the marginal lands. The pasturelands are degraded due to overgrazing caused by both increase in livestock population and decrease in area under grazing due to encroachment for cultivation and urbanization.

As a result more and more forests are being used for grazing purpose. At present nearly 70% of rainfed area is affected by wind erosion and sand deposition. Out of an estimated 142 million ha net cultivated area, about 86 million ha (60%) is rainfed. Even after reaching the full irrigation potential, nearly 50% of the cultivated area will remain rainfed.

At present about 60% of India's population as also 60% of livestock depends on agriculture. By 2025 AD, it is likely to reduce to 40% due to continued migration of rural people to semi urban/urban areas out of the projected population of 1.5 billion. The average land holding is likely to be 0.08 ha from the present 0.15 ha, which would be uneconomical for farming. Rainfed farmers are economically weak with little ability to withstand risk. Out of the 97 million farm holdings, 76 per cent are small.

- Most of the cropping in the arid and semiarid 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
    - Climatic constraints,
    - Soil related constraints,
    - Traditional cultivation practices
    - Heavy weed problem
    - Lack of suitable varieties and
    - Socio economic constraints.

3.1 Climatic constraints:

1. **Rainfall characteristics**: Among the different climatic parameters rainfall is an important factor influencing the crop production in dry regions are:

(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: 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 behavior**:

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.

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.

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.

iv) High atmospheric temperature: Because of high atmospheric temperature the atmospheric demand for moisture increases causing high evapo-transpiration losses resulting in moisture stress.

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

vi) Hot dry winds: Hot dry winds causes desiccation 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.

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

3.2 Soil related 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

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.

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.

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.

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.

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.

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.

3.3 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

3.4 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.

3.5 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.

3.6 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.

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

  a) Soil and moisture conservation
  b) Integrated soil fertility management
  c) Inter basin transfer of surface flow which is otherwise going as waste for seas and oceans
  d) Creation of live storage of water by constructing reservoirs
  e) Integrated water management of surface and ground water sources
  f) On farm irrigation water management to enhance water use efficiency

Lecture 4

SOIL AND CLIMATIC CONDITIONS IN RAINFED AGRICULTURE

4.1 Soils:

- Rainfed soils are generally of poor quality (low fertility, high erodibility, fragile, shallow and susceptible to loss of physical integrity).
- These have very weak buffering and resilience capacity.
- The soils suffer from excess of salts (saline-alkali soils) in arid and semi-arid areas and acids (acid soils) in sub-humid and humid areas.
- Micronutrients and ameliorants (mainly lime) are deficient and need supplementation periodically.
- The soils are mostly coarse textured, highly degraded with low water retentive capacity, multiple nutrient deficiencies, and thus are not conducive for intensive cropping.

The principal factors of soil formation are nature of parent material, climate, vegetation, soil organisms and topography, which are the same both in dry as well as in humid regions. However, in arid regions, physical weathering predominates soil formation. Erosion and re-deposition are the most important soil forming processes in arid regions. Rainfall is an important factor which affects the type and predominant properties of soils.

Soils developed in the semi-arid areas of Deccan Plateau are mainly Vertisols (black soils) and Alfisols (red and related soils), while in the arid zone of Rajasthan, they are Arid soils and Entisols.

Inceptisols and Mollisols occur in humid and sub-humid regions.

Soil order	Region/State	Area	
		Actual (m.ha)	(%)
Entisols	Rajasthan, Gujarat, Haryana	80.1	24.4
Inceptisols	Uttar Pradesh	95.8	29.1
Vertisols	Kovilpatti (T.N.), Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Karnataka, Andhra Pradesh	26.3	8.02
Aridisols	Haryana, West Rajasthan, Gujarat, Anantapur (A.P.)	14.6	4.45
Alfisols	Andhra Pradesh, Jhansi (U.P.), Tamil Nadu, Karnataka	79.7	24.3
Oxisols	Ranchi (Jharkhand), Bhubaneswar (Orissa)	0.3	0.1
Mollisols		8.0	2.4
Ultisols		0.8	0.2
Non-classified		23.1	7.0

In dryland regions, nearly 30 per cent of soils are covered by Alfisols and associated soils, 35% by Vertisols and associated soils (having vertic properties) and 10 per cent by Entisols of the alluvial areas.

Most of the Alfisols are sandy loams with a sub-soil alluvial layer of clay, less water retentive and prone to drought. The Vertisols are deep (15-240 cm) with a clay content of 30-70% and rich in bases. The clay types are smectite, montmorillonite and beidellite. The soils have high water holding capacity, frequently fertile and less drought prone.

4.2 Characteristics of Dryland soils:

- Dryland soils are generally low in organic matter and alkaline to slightly acidic in reaction in the surface have calcium carbonate ($CaCO_3$) accumulation in the upper 150 cm of soil layer, weak to moderate profile development, coarse to medium texture and having low biological activity.
- Nearly two-thirds of India's land mass has more than 3% slope and is highly undulating.
- The top soil shows many textural groups like loamy sand, sandy loam, loam, silt loam to clay loam.
- The soils are predominantly coarse textured and hence retain less water and nutrients. Crops grown on them are prone to drought and nutrient deficiencies.
- The low organic matter content is due to sparse vegetation producing little residues. The top soil when eroded, is devoid of organic matter, thus resulting in deficiencies of several nutrients.
- Removal of vegetation, intensive agriculture, uncontrolled and excessive grazing, and large unprotected fields devoid of protective vegetation are known to cause wind erosion.
- The inherent properties of dryland soils lead to degradative processes in rainfed semi-arid tropics, impose the following constraints for successful crop production
  1. Much reduced permeability.
  2. Poor or restricted root development
  3. Tillage and seeding problems
  4. Poor seedling establishment
  5. Uneven soil wetting
  6. Salinity and shallow water table and
  7. Poor soil fertility.

4.3 Climatic Constraints:

The drylands of the world show great diversity in their temperature characteristics and precipitation patterns.

4.3.1 Non-tropical drylands

- Cold (< 10° C) to mild winters (10-20° C)
- Mild (10-20° C) to very warm (> 30° C) summers.
- Moisture regime ranging from arid to semi-arid to sub-humid
- Variable precipitation patterns;
- Cold is a general but variable constraint, depending on severity of the winters, requiring adaptation of plants and crops;
- Agricultural systems are dominated by non-tropical crops with low water requirements (wheat, barley)

With winter-rainfall patterns:
Water needs of crops are lower as compared to tropical areas, therefore higher water use efficiency. C3-crops have a productivity advantage.

With summer rainfall patterns:
Water needs of crops are higher than in winter rainfall patterns, but usually lower than in tropical areas. C3-crops adapted to higher temperatures, or C4-crops adapted to lower temperatures, have a productivity advantage.

With transitional rainfall patterns:
Regimes with two rainy seasons, in summer and in winter, or with irregular unpredictable patterns.

4.3.2 TROPICAL DRYLANDS

- Warm winters (20-30° C);
- Warm (20-30° C) to very warm (>30° C) summers;
- Aridity regime ranging from arid to semi-arid to sub-humid;
- Summer precipitation regimes are the norm, although they can be shifted to autumn; bimodal rainfall in the Horn of Africa;
- In view of the generally warm winters the growing season is not limited by temperature, and cold is not a constraint for crops or plants. However, the water requirements are higher in view of higher evaporative demand of the atmosphere.

- Production systems are dominated by tropical crops (millet, sorghum, rice). C4-crops have a productivity advantage.

4.3.3 TRUE DESERTS

• Areas with hyper-arid moisture regimes
• Almost no perennial vegetation; agriculture and grazing are generally impossible.

Lecture 5

DROUGHT IMPORTANCE AN ITS TYPES/CLASSIFICATION

- 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

5.1 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) Acc. to American **Meteorological Society** defined drought as a period of abnormally dry weather sufficiently prolonged for lack of water *i.e.* due to absence of rain.

d) To agriculturalist drought means deficiency of soil moisture in crop root zone.

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. So to hydrologist drought means lowering of water in lakes, reservoirs etc.

5.2 Based on rainfall deficit we are having three terms:

1. **Dry spell:** Rainless period for short time (*i.e.*, >10 days in light soils, >15 days in heavy soils). The interval between the end of a seven day wet spell, beginning with the onset of effective monsoon and another rainy day with 5 e mm of rain (where "e" is the average daily evaporation).
2. **Drought**: Prolonged dryspell resulting in wilting or drying of crops.
3. **Famine**: Severe form of drought called as famine.

5.3 Classification of drought:

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

5.3.1 Based on duration

- **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.

  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.

  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.

  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.

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

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). As per precipitation, the below normal departure of rainfall was classified by the IMD, India, as mild (1- 25%) moderate (26 – 50%) and severe (above 50%). This is also a period of abnormally dry weather which is as per spatial extent sufficiently prolonged. Droughts are considered as large scale (up to 25% area is affected) and worst (from 26 to 50% area affected).

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. (Midday depression or incipient wilting).

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.

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.

Agricultural drought is again classified into five major types (in dryland areas) :

Early season drought: The early season drought occurs due to delay in commencement of sowing rains. Farmers sow the seed by taking advantage of early rains. A long dry spell may lead to withering of seedlings and poor crop establishment.

Mid season drought: This occurs in association with long gaps between two successive rain events, if moisture stored in the soil falls short of water requirement of crop during the dry period. On other occasions the mid season drought may be associated with low and inadequate rainfall in the growing season to meet the crop water needs as per the phenological stage.

Late season or terminal drought: If the crop encounters moisture stress during the reproductive stage due to early cessation of rainy season and rise in temperature the situation hastens the process of maturity.

5.3.3 Other terms to describe drought:

Relative/ Apparent 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.

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.

5.3.4 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

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

Lecture 6

Effects of drought on crop production

6.1 **Water relations:**

Alters the water status by its influence on absorption, translocation and transpiration. The lag in absorption behind transpiration results in loss of turgor as a result of increase in the atmospheric dryness. As moisture stress increases, turgidity of guard cells decreases. Due to water deficit leaf and canopy temperatures of plant increases. To reduce the temperature in plant stomata starts closing during day time.

6.2 **Photosynthesis:**

Photosynthesis is reduced by moisture stress due to reduction in Photosynthetic rate, chlorophyll content, leaf area and increase in assimilates saturation in leaves (due to lack of translocation). Due to water deficit leaf and canopy temperatures of plant increases. To reduce the temperature in plant, stomata starts closing during day time. As a consequence, the entry of CO_2 into plant reduces.

6.3 **Respiration:**

Respiration increases with mild stress. If water deficit becomes severe, respiration decreases. More severe drought lowers water content and respiration.

6.4 **Anatomical changes:**

Decrease in size of the cells and inter cellular spaces, thicker cell wall greater development of mechanical tissue. Stomata per unit leaf tend to increase under moisture stress.

6.5 Metabolic reaction:

All most all metabolic reactions are affected by water deficits. Severe water deficits cause decrease in enzymatic activity. Accumulation of sugars and aminoacids takes place under moisture stress. **Proline,** an aminoacid accumulates whenever there is moisture stress.

6.6 Hormonal Relationships:

The activity of growth promoting hormones like cytokinin, gibberlic acid and indole acetic acid decreases and growth regulating hormone like abscisic acid, ethylene, etc., increases due to moisture stress. **Abscisic acid** acts as water deficit sensor to minimize the loss of tissue water potential. Ethylene production induced by moisture stress is considered to be the cause for leaf and tissue water potential. **Ethylene production** induced by moisture stress is considered to be the cause for leaf and fruit drop. **Betain** is another hormone produced by the moisture stressed plants and it is used as an indicator of moisture stress.

6.7 Nutrition:

The fixation, uptake and assimilation of nitrogen is affected. Nitrogen fixation by leguminous plants is reduced by moisture stress due to reduction in leghaemoglobin in nodules, specific nodules activity and number of nodules. Since dry matter production is considerably reduced the uptake of NPK is reduced.

6.8 Growth and Development:

The expansion of cells and cell division are reduced due to moisture stress resulting in decrease in growth of leaves, stems and fruits. Moisture stress affects germination, leaf area, leaf expansion and root development. Maturity is delayed if drought occurs before flowering while it advances if drought occurs after flowering.

Development: In general, moisture stress delays maturity. If stress occurs before flowering, the duration of crop increases and when it occurs after flowering, the duration decreases.

6.9 Reproduction and grain growth:

Drought at flowering and grain development determines the number of fruits and individual grain weight, respectively. Panicle initiation in cereals is critical while drought at anthesis may lead to drying of pollen. Drought at grain development reduces yield while vegetative and grain filling stages are less sensitive to moisture stress.

Pod abortion takes place due to drought in several legumes including in soybean. Drought decreases photosynthetic rate and water potential in leaves, flowers and pods. Drought decreases leaf sucrose and starch concentrations but increased hexose (Glucose + Fructose) concentrations.

6.10 Yield:

The effect on yield depends hugely on what proportion of the total dry matter is considered as useful material to be harvested. If it is aerial and underground parts, effect of drought is as sensitive as total growth. When the yield consists of seeds as in cereals, moisture stress at flowering is detrimental. When the yield is fibre or chemicals where economic product is a small fraction of total dry matter moderate stress on growth does not have adverse effect on yields.

Lecture 7

Mechanism of crop adaptations under moisture deficit condition

7.1 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

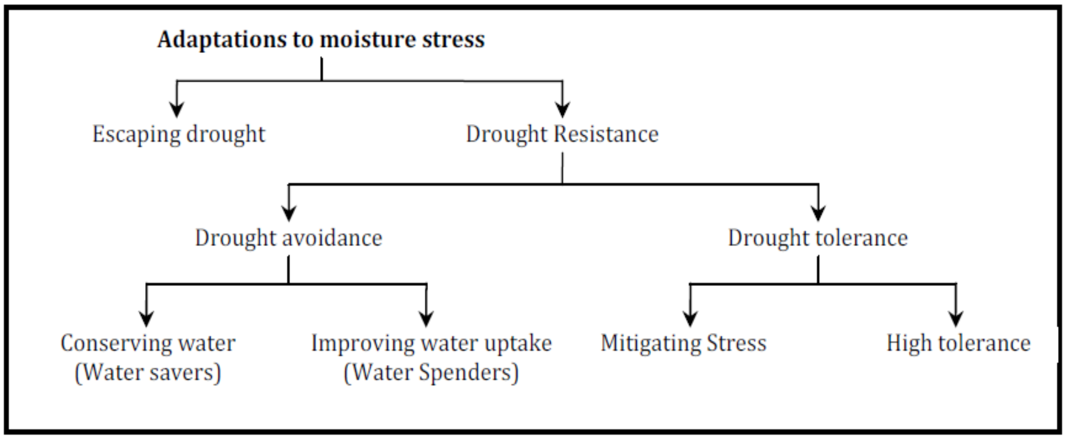

Fig. 4.1 Flow chart showing different mechanisms for overcoming moisutre stess

7.2 Escaping Drought

- **Escaping** the drought period is the simplest means of adaptation of the plants under dry soil conditions.
- Many desert plants, Ephemerals have an extremely short life period (5 to 6 weeks). So they germinate at the beginning of the rainy season and completes its lifecycle by the end of rainy period.
- These plants do not have mechanism for overcoming moisture stress therefore these are 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. EX: Certain varieties of pearl millet mature within 60 days after sowing, Short duration pulses like cowpea, greengram, blackgram can be included in this category.

7.3 Drought Resistance

- The ability of a crop species or variety to grow and yield satisfactorily in areas subjected to periodic water deficits is termed as drought resistance
- Plants can adopt to drought either by avoiding stress or by tolerating stress due to different mechanisms. These mechanisms provide drought resistance.

7.4 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.

7.4.1 Conserving water:

1. By closing stomata we can reduce the transpiration (stomata will be closed due to increase in ABA concentration, thereby reducing water loss).
2. These (CAM) plants store enough water in their tissues. They open stomata at night. They have thick leaves and possess modifications (such as phyllodes and phylloclades) under water stress conditions. They fix carbon during day time with the help of malic acid and CO_2, which is released internally during respiration.
3. By developing smaller leaves with thick cuticle
4. By increasing photosynthetic efficiency. (C_4 crops should be grown under these conditions because they will have high photosynthetic efficiency to supply water compared to C_3 crops because of the presence of enzyme PEP Carboxylase)
5. Having sunken stomata with hairs (pubescence) to reflect light and to reduce the transpiration eg. Soybean, Nerium
6. Shedding their leaves during summer to avoid excess water loss
7. Dehydration of protoplasm
8. Reducing enzyme activity
9. By developing awns, thorns in some crops.
10. By deposition of lipids on the leaf surface to reflect light. Ex: Sorghum, Sugarcane etc.
11. Favoring the syntheses of ABA (stress hormone) and Ethylene (senescence hormone)

7.4.2 Water uptake:

The plants try to uptake more water whenever water is available and act as a water conservers in the future for the growth and development of the crop. Water uptake is done by either more development of roots, root- shoot length.

1. Development of adventitious roots helps the plant to absorb more water and keeps the plant for survival.

2. The crops selecting should have high root length instead of shoot length. Because if more shoot length and less root length is there means less absorption of water and more transpiration will be there. If mote root than shoot means vice versa will be there and conserves moisture in the metabolism of the plant.
3. Hydraulic conductance of plants (increasing either the diameter of xylem vessels or their numbers).

7.5 Drought tolerance with low tissue water potential: The ability of the plant to endure periods without significant rainfall and to endure low tissue water potential. Ability to produce flowers with a minimum of vegetative structure enables them to produce seeds on a limited water supply.

7.5.1 Mitigating stress:

An important aspect of developmental plasticity is the ability of plants to transfer assimilates accumulated prior to seed-filling to the grain during the seed filling stage. It was also suggested that when sufficient water supply is there the food materials stored will be supplied to the grain from the stems and roots in small amounts, but when stress occurs in the seed filling stage, an increased proportion of the prior assimilate is transferred to the seed.

7.5.2 Desiccation Tolerance

Based on the desiccation tolerance of the protoplasm, plants can be classified as poikilohydric or homohydric plants.

1) Poikilohydric (resurrection plants)

The protoplasm of poikilohydric plants can withstand almost complete dehydration and can also withstand dehydration and rehydration in concert with available water without damage.

2) Homoiohydric plants

Majority of the plants are homoiohydric plants. During growth and development, the protoplasm of homoiohydric plants cannot withstand low water potential without injury. Dehydration caused mechanical injury to the protoplast by physical tearing and destruction during water extraction and shrinkage.

Small cells with no vacuoles and also the cells that lose their vacuoles and also the cells that lose their vacuoles during dehydration can withstand the most severe desiccation without mechanical injury. **The changes in viscosity of the protoplasm and permeability of the membrane play a role in desiccation tolerance**. Sugars play a role in protecting this mechanism in desiccation resistant species and varieties. Sugars may also provide protection against desiccation.

Biochemical effect of drought tolerance

1) Accumulation of Proline, Glycine, betaines *etc.*
2) Synthisis of Abscisic acid (ABA) *etc.*

Lecture 8

STRATEGIES FOR DROUGHT MANAGEMENT

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

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

- **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.
- **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.

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

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

b) **Spraying**: In crops like groundnut, castor, 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 midseason correction measure after break of dry spell.

d) **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.

e) **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.

8.3 Giving life saving irrigation & Water harvesting: 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.

8.4 Soil moisture conservation through watershed development, check dams, contour bunding

8.5 Drought tolerant varieties

8.6 Green manure treatment

8.7 Vegetative barriers

8.8 Rehabilitation of wastelands

8.8.1 Continuous monitoring of the environmental variable is one of the ways to track the occurrence of drought

8.8.2 Deepening of old wells, digging of new wells, drilling of boreholes

8.8.3 Construction of multipurpose dams

8.8.4 Timely availability of credit, postponement of revenue collection, and repayment of short term agricultural loans

8.8.5 Implementation of crop and livestock insurance schemes

8.8.6 Early warning and drought monitoring should be carried out on the basis of long, medium and short term forecasts

8.8.7 Education and training to the people

8.8.8 Participation in community programmes

8.8.9 Bring public awareness of drought and water conservation

8.8.10 Media awareness programme.

Lecture 9

Water harvesting and life saving irrigation

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.

9.1 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.

9.2 Runoff water induced by the following methods

- 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.

9.2.1 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.

9.2.2 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.

9.3 Methods of Water Harvesting

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

9.3.1 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.

9.3.1.1 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.

9.3.1.2 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.

9.3.1.3 Traditional water harvesting systems: Tanka, nadi, khadin are the important traditional water harvesting systems of Rajasthan.

9.3.1.4 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 lt.

9.3.1.5 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

9.3.1.6 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.

9.3.2 Semiarid Regions

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

9.3.2.1 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.

9.3.2.2 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.

9.3.2.3 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 Percolation tank

9.3.2.4 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.

Fig. 15.2 Farm Pond Lined with Kadapa Slabs

- 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., 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 Anantapur (A.P.), soil without sieving and cement in 6:1 ratio 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).

Fig .15.3 Farm Pond lined with Cement Bricks

Fig. 15.4 Farm Pond Lined with Fire Bricks

- 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.

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

Lecture 10

Contingent Crop Planning For Aberrant Weather Conditions

10.1 Effect of aberrant weather conditions on crops

- Rainfall behavior in dry farming areas is erratic and uncertain.
- The deviations in rainfall behavior commonly met with in dry areas include delayed onset, early withdrawal and intermediary dry spells during rainy season.
- Suitable manipulations in crop management practices are needed to minimize such adverse effects of abnormal rainfall behavior.
- 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.

Rainfall aberrations	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
Intermediate dry spells	
2. Immediately after sowing	Germination will be affected, plant population will be reduced
3. At vegetative stage	Affects stem elongation, leaf area expansion, branching or tillering
4. At flowering	Affects anthesis and pollination, grain / pod number is reduced
5. 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.

Or

To mitigate any unexpected, unfavorable, accidental weather conditions without prior information at any time before sowing or after sowing of crop.

- ❖ 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.

10.3 Six types of contingent crop plans. The types are:

1. Inadequate and Uneven Distribution of Rainfall
2. Long Gap in Rainfall
3. Early Onset of Monsoon
4. Late Onset of Monsoon
5. Early Cessation of Rains
6. Prolonged Dry Spells.

10.3.1 Contingent Crop Plan in Inadequate and Uneven Distribution of Rainfall

In general, the rainfall is low and highly variable which results in uncertain crop yields. Besides its uncertainty, the distribution of rainfall during the crop period is uneven, receiving high amount of rain, when it is not needed and lack of it when crop needs it.

a) Short duration crops grown
b) Cultivation of low water required crops
c) Providing life saving irrigation

10.3.2 Contingent Crop Plan for Long Gap in Rainfall:

a. Increase in seed rate to obtain more population
b. Spraying of urea solution
c. Providing life saving irrigation at critical growth stages
d. Weeding and intercultural operations

10.3.3 Contingent Crop Plan for Early Onset of Monsoon:

a) Cultivate Pearl millet, Sesame etc.
b) Grow short duration crops
c) Moisture conservation practices should be followed
d) Use cultural methods to mitigate stress

10.3.4 Contingent Crop Plan for Late Onset of Monsoon:
Due to late onset of monsoon, the sowing of crops is delayed resulting in poor yields.

a. Alternate crop & varieties: Castor (Aruna), green gram, cowpea, sunflower
b. Dry sowing/Kurra sowing
c. Pre sowing
d. Seed soaking/treatment
e. Alternate crops/ varieties
f. Transplanting of one month old Bajra seedlings.
g. Complete weed control
h. Grow legumes/oilseed crops in place of cereals
i. Most suitable crop for this condition is Sunflower.

10.3.5 Contingent Crop Plan for Early Cessation of Rains:

Sometimes the rain may cease very early in the season exposing the crop to drought during flowering and maturity stages which reduces the crop yields considerably:

a. Select short duration varieties
b. Using mulching/mulches
c. Life saving irrigation applied
d. Decrease in plant population

10.3.6 Contingent Crop Plan for Prolonged Dry Spells:

Long breaks in the rainy season are an important feature of Indian monsoon. These intervening dry spells when prolonged during crop period reduces crop growth and yield and when unduly prolonged crops fail.

a) If mild moisture stress at 30-35 days after sowing, thinning of alternate rows of Sorghum and Pearl millet
b) If severe moisture stress at 30-35 days after sowing, cutting of sorghum and Pearl millet and rationing
c) If moisture stress at blooming stage, cutting of sorghum and Pearl millet and rationing
d) Breaking of monsoon for short while, shallow inter cultivation for eradicating weeds/soil mulch
e) Wider spacing for moisture conservation
f) Spray of 2 % urea after drought period is useful for indeterminate crops like castor, pigeon pea and groundnut

g) Soil mulching to reduce evaporation losses
h) Life saving irrigation
i) If dry spell in 10 days of sowing, resowing
j) Weed control to save water, nutrients

10.3.7 Contingent Crop Plan for dryspell during crop growing period:

a) Ratooning
b) Mulching
c) Thinning

- Crops have to be selected with suitable crop duration to coincide with the length of the growing season.

Cyclone 'Hudhud' made a landfall on 12th October 2014 at Visakhapatnam and caused serious damage to agriculture in four districts each in Andhra Pradesh and Odisha. State wise crop advisory is given below for reference and adoption and contingency measures to minimize and prevent further damage in standing corps.

Andhra Pradesh

North coastal districts of Andhra Pradesh (Visakhapatnam, Srikakulam, Vizianagaram and East Godavari) suffered widespread damage due to gale accompanied by downpour.

Crops affected	Damage	Advisory/ Contingency measures
Rice	Crop in various growth stages affected due to partial or complete lodging due to high speed winds and partial inundation due to accompanying rain. Long duration crop varieties are in panicle initiation to grain filling stage while medium maturing varieties are in flowering stage. Rice at flowering stage has been seriously affected. Flood is imminent in low lying villages of Srikakulam district in	• Drain out excess water by making alleys at periodic intervals in the lodged crop • Take up staking of plants at grain filling stage • After flood water is receded, apply 25 Kg urea and 10-15 Kg of MOP as booster dose to long duration varieties • Apply 15-20 Kg of Potash or spray of multi-K (13-0-45) @ 10 g/l of water for medium duration varieties • Early planted rice which is in maturity stage may be sprayed with 5% salt solution to prevent seed germination • Spray hexaconozole @ 2ml/l as prophylactic spray to prevent occurrence of sheath blight/blast disease incidence • Spray streptocycline @ 0.1 gm/l if bacterial leaf bl[illegible] is noticed (varieties: BPT – 5204, MTU-1001, MTU-1075) • In partially lodged crop in panicle initiation stage especially in long duration and susceptible fine rice varieties, keep a watch on brown plant hopper

	the command areas of Nagavali river due to heavy inflows.	population at the base of plants. Observe if population is in rising trend as conditions are conducive for pest outbreak if drizzly and cloudy weather conditions prevail for few more days. Apply need based spray immediately after cessation of rain based on close monitoring of pest incidence
Maize	Lodging and stress due to excess soil moisture	• Staking of lodged plants • Provide quick drainage of excess water by opening furrow • Harvest cobs at physiological maturity or marketable green cobs or for fodder purpose in case crop is badly damaged • Undertake earthing up of plants in partially affected fields • In mild to moderately affected fields due to lodging/uprooting, take up prophylactic or need based spray to prevent fungal diseases (blight & rot)
Oilseeds (groundnut and sesame)	Lodging in sesame, water logging in groundnut	• Harvest at physiological maturity of pods in sesame, undertake quick drying, threshing, safe storage/marketing • Provide quick reduction in soil moisture in groundnut fields to prevent premature germination by opening of drainage channel immediately after flood water recedes and harvest at physiological maturity • In slightly affected water logging groundnut fields take up need based spray of fungicide (chlorothalonil @ 2g/l) to prevent late leaf spot incidence • In case of severe shortage of green fodder to milch cattle, harvest groundnut and use haulms for feeding
Short duration pulses and pigeon-pea	Water logging in pulses and lodging in pigeon pea	• Harvest late planted pulses (blackgram & greengram) at physiological maturity • Provide early drainage from water logged fields • Use damaged plants as fodder to milch cattle • Stake lodged plants in pigeonpea and undertake earthing up of plants at the earliest opportunity for tillage • In badly affected fields due to water logging, harvest crop for fodder purpose
Sugarcane	Lodging and water logging	• Staking of lodged plants • Provide quick drainage by opening furrows • Earthing up of affected plants

Vegetable crops	Lodging and water logging in tomato, brinjal, raddish and cucurbit crops	• Standing crops damaged due to lodging and water logging • Harvest produce at the earliest opportunity undertake shifting, grading and marketing of produce • Harvest at physiological maturity • Undertake nipping of apical buds to induce sympodial branching to compensate for production loss • Apply light booster dose for fertilizer • If soil application is not possible, apply foliar spray of 2% urea/DAP 0.1% MOP • To prevent root, foliar and fruit diseases (rot, leaf spot, blight), apply foliar spray of fungicides/bactericides (Mancozeb 2g/l, carbendazim, 1g/l, copper oxy chloride 3g/l, plantamycin 0.6g/l) or soil drenching with copper oxy chloride 30g/l)
Coconut, Banana, Cashew & pulpwood plantations (Casurina, Eucalyptus etc)	Breaking of branches, lodging, partial or complete uprooting of trees	• Propping/staking of partially lodged/uprooted trees • In banana, remove lodged plant to allow one good sucker to replace the lost plant • Prune broken branches of trees (flat cut at breakage point) and apply Bordeaux paste to cut end • Apply booster dose of fertilizer after optimum moisture conditions return in the orchard • For coconut, apply COC 3g/l of water in whorls after clearing the broken/dropped leaves in young trees • Fresh planting may be taken up in place of the lodged, uprooted older trees • Under take gap filling in the orchard in case of complete loss of plants due to uprooting in plantation crops

Odisha

Gajapati, Koraput, Malkangiri and Rayagada were the worst affected districts. Detail of crop damage and contingency measures are give below:

Crops affected	Damage	Advisory
Paddy	Lodging, partial submergence	• Staking of lodged plants • Make alleys at intervals to clear excess water • Apply N @ 20 Kg/ha for quick recovery in late rice or spray 2% urea to crop in flowering stage • Heavy rainfall is likely to trigger outbreak of swarming caterpillar and cut worm (panicle stage) in late rice. Apply need based spray of chlorpyriphos @2 ml per 1itre • Prophylactic spray of copper oxychloride, streptocycline and imidacloprid to prevent bacterial leaf blight, blast and insect attack (BPH) where crop is badly affected and loss is complete, contingency crops like short duration greengram followed by sesame are suggested.
Pulses and Groundnut	Water logging	• Provide quick drainage • Harvest at physiological maturity to prevent premature germination • Use residue for fodder purpose
Mango and Papaya, Teak and Cashew	Lodging, breaking, uprooting of plants	• Provide quick drainage in orchards/plantations • Prune broken branches in orchard crops and apply Bordeaux paste to cut ends • Propping of papaya plants and harvesting of marketable fruits • Earthing and staking of lodged plants and application of the booster dose of fertilizer
Vegetable crops	Tomato, Brinjal, Chillies	• Provide quick drainage • Practice earthing up of plants • Harvest at physiological maturity/marketable produce. • Take up plant protection measures through foliar spray of fungicides (copper oxy chloride 3g/l) or drench soil at the base of plant to prevent rot/wilt • Apply light booster dose of fertilizer under optimum soil moisture conditions to stimulate growth • Practice nipping of apical buds to promote sympodial branching

Lecture 11

Watershed management – objectives and approaches

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.

11.1 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.

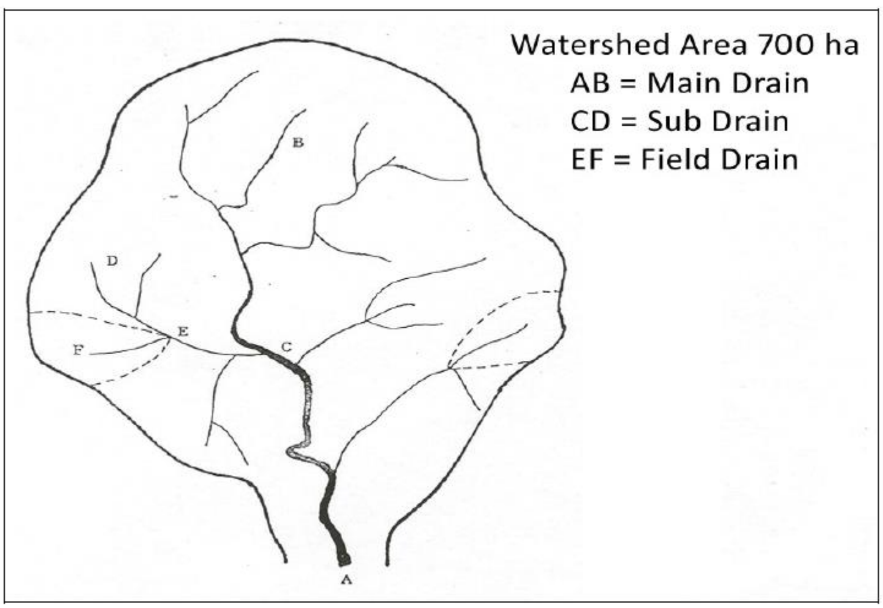

Fig. 12.1 watershed with main and sub drains

- 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.

- 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.

11.2 History of watershed management:

Watershed management has been taken up under different programmes launched by Government of India.

1. In 1962 – RVP (Soil conservation work in catchments of river valley projects) was established.
2. In 1977-78- ministry of rural development started programme " DDP- Desert Development Programme" for hot areas like Rajasthan, Haryana, J&K.
3. In 1980- ministry of of agriculture started a scheme- Integrated watershed management in catchments of flood prone rivers.
4. In 1982- Water harvesting/ water conservation techniques in rainfed areas were started in 19 locations in India.
5. In 1987 - The Drought Prone Area Development Programme (DPAP) and the Desert Development Programme (DDP) adopted watershed development approach.
6. In 1989- The Integrated Watershed Development Project (IWDP) taken up by the National Wasteland Development Board (NWDB).

11.3 Watershed development programmes developed under different departments:

1. Under Department of Agriculture

NWDPRA- National Watershed Development Project for Rainfed Areas.

RVP- Soil Conservation in Catchments of River Valley Projects

WDPSCA- Watershed Development Project in Shifting Cultivation in Area

WDF- Watershed Development Fund

2. Under Ministry of Rural Development:

DPAP- Drought Prone Area Programme

DDP- Desert Development Programme

IWDP- Integrated Wasteland Development Programme

3.**Under Ministry of Environment and Forests**

IAEDP- Integrated Afforestation and Eco development Projects and Schemes

11.4 Based on the size, shape & drainage the watersheds may be classified as

1. Macro watershed - >50,000 ha
2. Sub macro watershed- 10,000-50,000ha
3. Milli watershed- 1000- 10,000ha
4. Micro watershed- 100-1000ha
5. Mini watershed- 1-10ha

11.5 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.
- Expansion of recreation facilities such as picnic and camping sites.

Objectives:

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

Lecture 12

12.1 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

12.2 Action plan for watershed development (steps in watershed management)

12.2.1 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.

12.2.2 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

12.2.3 Analysis of problems and identification of available solutions

12.2.4 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

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

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

12.2.7 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

12.2.8 Monitoring and evaluation to assess the progress of the project and to suggest modification if any

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

12.2.10 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

12.3 Watershed Management: Components

Components:

1. Soil And Water Conservation Measures
2. Water Harvesting
3. Crop Management
4. Alternate Land Use System
5. Biomass Management
6. Land Use Classification

12.3.1 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:

1. **Permanent treatments (Hardware treatments)**
2. **Semi permanent treatments (medium software treatments) and**
3. **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**.**

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

2. **Bunds:** contour bunds –Suitable for low rainfall areas (< 600 mm) and in permeable soils having slope up to 6%.
3. **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.**
4. **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 inter bund 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.

1. **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.
2. **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**.**
3. **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.
4. **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.

12.3.2 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.

Methods of Water Harvesting

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

Arid Regions

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.

Micro catchments: 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 micro catchment, a basin is dug about 40 cm deep and a tree is planted in it. The basin stores the runoff from micro catchment.

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.

Nadi or village pond is constructed for storing water from natural catchments. The capacity of nadi's 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.

Semiarid Regions

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.

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.

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.

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.

12.3.3 Crop management

The land management refers to keep all those properties of land in proper order, which likely to affect the soil yield potency. The land characteristics such as terrain, slope, formation, depth, texture, moisture, in-filtration rate and soil capability are the main to consider under land management activities for watershed development.

includes following activities:

a. Vegetative measures

b. Structural measures

c. Production measures; and

d. Protection measures.

a. Vegetative measures: These are the primary land management measures.

1. The development of grass lands/pasture lands for erosion/soil loss control
2. Adoption of contour farming and strip cropping practices on hill faces
3. Growing of vegetations on barren lands or by simply keeping the land under vegetations.

These measures are very effective to check the **soil erosion**, along with less cost expensive and easily practicable for the farmers.

- ❖ The practices such as development of vegetative cover, plant cover, mulching, vegetative hedges, grassland management, agro-forestry etc., are also included under this kind of measures.

b. Structural measures: These include mechanical conservation measures such as bunding, terracing, check dams etc., are used at the steep lands for controlling the soil loss, especially when vegetative measures are ineffective.

- These measures are not so common as the vegetative measures because of involvement of heavy expenditure of money.
- Similarly, the gully plugging structures like drop structures, spillways etc., used for gully control; and farm ponds used for safe water storage in the farmland area, are also considered as mechanical measures for land management.
- These structures offer their immediate effect on soil erosion/soil loss check, but very cost expensive, requires proper site selection, design and construction. Because of this reason, their construction is not possible by the farmers; the government normally executes it.

c. Production measures for land management include the practices such as mixed cropping, strip cropping, cover cropping, crop rotations, cultivation of shrubs and herbs, contour cultivation, conservation tillage, land leveling, use of improved variety seeds, horticultural practices etc.

- The objective of these measures is to enhance the production potential of the land either by conserving the soil or enriching the nutrient status.

d. Protective measures are the landslide control structures, gully plugging structures, runoff collection structures etc. Adoption of these measures depends very much on the land characteristics.

e. Selection of crops and cropping systems to suit length of growing season
f. Optimum sowing time
g. Fertilizer schedules and balanced use of plant nutrients for crops and cropping systems
h. Weed management and package of practices for aberrant weather
i. Contingent cropping

12.3.4 Alternate land use systems: Alternate land use systems are discussed

Definition: 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.
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:

1. **Agri-silviculture**

This alternate land use system combines perennial arboreal 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

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

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.

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, pomegranate, custard apple, sapota and mango. Pulses are the important arable crops for this system.

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)**

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**. 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 pruning's 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.

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.

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.

9. **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.

12.3.5 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 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. 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. 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, watersheds and wild life** etc.,

Lecture 13

Factors affecting watershed management

13.1 Watershed characters **(**Size and shape, Topography& Soils **)**

13.2Area and Length of Watershed

13.3 Climatic characteristics

1. Precipitation
2. Amount and intensity of rainfall

13.4 Land use pattern

1. Vegetative cover
2. Density

13.5Social status of inhability

13.1.1 Size and shape

1. Size of watershed determines the quantity of rainfall received, retained and disposed off (runoff). A small watershed is pronounced by overland flow which is main contributor to result in peak flow.
2. While a large watershed has no overland flow significantly, but channel flow is the main characteristic. Large watersheds are also affected by basin storage.
3. Watershed size interacts with the extent of land use changes, as well as factors that affect weather and climate.
4. In smaller watersheds, the predominant interaction is between weather scale runoff-causing events storm whereas, in larger watersheds, the predominant interaction is between climate-scale runoff-causing events. While large-scale events or land use changes may impact small watersheds

13.1.2 Shape

1. Common watershed is square, rectangular, oval, fern leaf shaped, polygon-shaped, circular or triangular type and long or narrow.
2. Larger the watershed, higher is the time of concentration of runoff
3. So more water will infiltrate and utilized by the vegetation.
4. Shape of the land is determined by geology and weather.
5. It greatly influences drainage patterns.
6. Density of streams and the shape of a watershed in turn, affect the rate of overland runoff relative to infiltration.

7. A circular watershed would result in runoff from various parts of the watershed reaching the outlet at the same time.
8. An elliptical (oval) watershed having the outlet at one end of the major axis and having the same area as the circular watershed would cause the runoff to be spread out over time. Thus, produces a smaller flood peak than that of the circular watershed

13.1.3 Topography

- Topographic configuration such as slope, length, degree and uniformity of slope affect both disposal of water and soil loss.
- Time of concentration and infiltration of water are a function of these.

13.1.4 Slope of Watershed

- Watershed slope affects the velocity of runoff.
- Significant variation in the slope along the main flow path gives rise several sub-watersheds

13.1.5 Soil

1. Physical properties of soil, specially texture, structure and soil depth influence disposition of water by way of infiltration, storage and runoff.
2. Soil types influence the rate of water movement (lateral and vertical)
3. Finely grained soils, such as clays, have very small spaces between soil particles inhibiting infiltration and thus promoting greater surface runoff.
4. Coarse textured soils, such as sands, have larger pore spaces allowing for greater rates of infiltration and reduced runoff.
5. Surface roughness, soil characteristics such as texture, soil structure and soil moisture affect the runoff in various ways.
6. Generally soils with a significant portion of small particles have low infiltration capacity, whereas sandy soils have high infiltration capacity.

13.2.1 **Area of Watershed**

- Determination of a workable size of watershed area is important for a successful watershed management programme

13.2.2 **Length of Watershed**

- The watershed length is measured along the principal flow path from the watershed outlet to the basin boundary.

- As channel does not extend up to the basin boundary, So it requires to extend a line from the end of the channel to the basin boundary.

13.3 Climatic characteristic

Climate parameters affect watershed its manipulation in two ways.

1. Precipitation
2. Amount and intensity of rainfall

- The amount of rainfall and these parameters along with temperature, humidity, wind velocity, etc. regulates factors like soil and vegetation.
- Soil properties reflect the climate of the region.
- In the same way, the vegetation type of a region depends totally on the climate type.

13.4 Land use pattern, Land Cover and vegetation

Vegetation

Type of vegetation regulates the functioning of watershed;

Ex: Infiltration, water retention, runoff production, erosion, sedimentation

- Vegetation plays vital roles in the water cycle.
- Intercepts rainfall, impedes overland flow and promotes infiltration.
- Vegetation also uses water for growth.
- All of these factors reduce the quantity of runoff to streams.
- Vegetation binds and stabilizes soil thus, reduces the erosion.
- Vegetation also stabilizes stream banks and provides habitat for aquatic and terrestrial fauna.

13.5 Social status of inhability

By giving priority to the local people – a good step in itself –where more people are making decisions.

- Arising awareness of the people’s role in the watershed approach
- Village communities, are made aware and are convinced of the advantages of this approach, i.e. the mobilization of the rural communities and their greater involvement in development programmes and project.
- Strengthening the capabilities of local organizations.
- Decentralization of decision-making by all players concerned, including those outside of watershed areas.