Lecture 10: Water Harvesting, Storage and Recycling

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

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

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

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

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

Inducing Runoff

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

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

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

Methods of Water Harvesting

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

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

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

b) 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.

c) Traditional water harvesting systems: Tanka, nadi, khadin are the important traditional water harvesting systems of Rajasthan. Tanka is an underground tank or cistern constructed for collection and storage of runoff water from natural catchment or artificially prepared catchment or from a roof top. The vertical walls are lined with stone masonary or cement concrete and the base with 10 cm thick concrete. The capacity of the tank ranges from 1000 to 6, 00,000 litre, Nadi or village pond is constructed for storing water from natural catchments. The capacity of nadis ranges from 1200$m^3$to 15000 m^3.Khadin is unique land use system where in run off water from rocky catchments are collected in valley plains during rainy season.

2. Semiarid Regions

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

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

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

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

d) Farm Ponds: These are small storage structures for collection and storage of runoff water. Depending upon their construction and suitability to different topographic conditions farm ponds are classified as

- Excavated farm ponds suitable for flat topography
- Embankment ponds for hilly terrains and
- Excavated cum Embankment ponds

There are three types of excavated farm ponds ; square, rectangular and circular. Circular ponds have high water storage capacity. Farm ponds of size 100 to 300 m3 may be dug to store 30 per cent of runoff. The problem associated with farm ponds in red soils is high seepage loss. This can be reduced by lining walls. Some of the traditional methods for seepage control are the use of bentonite, soil dispersants and soil-cement mixture. Bentonite has excellent sealing properties if kept continuously wet, but cracks develop when dried. Soil-cement mixture can be used. A soil-cement lining of 100 mm thickness reduces seepage losses up to 100 per cent.

The 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 percentage of runoff ranges from 10 to 30% of total rainfall. The size of the farm pond depends on the rainfall, slope of the soil and catchment area. The dimensions may be in the range of 10 m x 10 m x 2.5 m to 15 m x 15 m x 3.5 m. The side slope 1.5: 1 is considered sufficient. A silt trap is constructed with a width of slightly higher than the water course and depth of 0.5 to 1 m and with side slope of 1.5: 1.

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

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

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

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

c) Method of irrigation: Surface methods of irrigation like check basin, basin, and furrow methods are not suitable for supplemental irrigation, mainly for three reasons : the rain fed lands are uneven, conveyance losses may go up to 30% and limited amount of water available for irrigation. Drip and sprinkler irrigations are more suitable because small amount of water can be delivered, even on uneven soils without conveyances losses. Subsurface drip irrigation is very efficient for providing supplemental irrigation. The main drawback of micro-irrigation system is high initial cost of the system. Pot watering is another efficient method being used by the farmers for transplanting crops like tobacco, chilly, tomato etc.,

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

Lecture 11: Integrated dry land technologies and farm mechanization

Integrated dry land technology and its components: A single technology in isolation will not give desired results. Adoption of all related technologies as an integrated dry land technology package alone will provide a synergistic effect and improve the crop productivity in dry regions. The various components of such an integrated dry land technology (IDLT) are the following.

- In situ soil moisture conservation
- Choice of suitable crops and crop substitution
- Selection of high yielding drought tolerant varieties
- Cropping system to suit rainfall quantity, duration of rainy season and soil moisture storage
- Tillage to conserve moisture
- Establishment of optimum population
- Soil fertility management
- Crop protection against weeds, pests and diseases.

INTEGRATED FARMING SYSTEMS IN DRYLANDS

Integrated farming system (IFS) refers to the adoption of allied agricultural enterprises along with crop production in a mutually beneficial manner in the same farm holding. Eg. Crop + sheep / goat, crop / sericulture, Crop + poultry, crop / tree + forage + livestock.

IFS offers many advantages compared with annual cropping alone.

- Increased farm income
- Stability in farm income
- Increased employment opportunities
- Balanced food to farm family
- Efficient use of resources
- Recycling of farm wastes.

Case studies in dryland IFS

Black soils of Kovilpatti

IFS	Crop + Live stock
a) Crop (0.5 ha)	Cotton, sun flower, sorghum
b) Fodder crops (0.5 ha)	*Cenchrus cilaris*, fodder cumbu, fodder sorghum
c) Livestock	2 Jerssy milch cows

System	Net income Rs/Year
1. Crop	1636
2. Additional income from milch animal	2519
3. Organic matter recycled	1.2 tonnes per year

Black soils of Aruppukottai

IFS	Crop + trees + goat
Crop	Sorghum + cowpea, Cotton + Blackgram
Fodder	Cenchrus grass + Desmanthus
Fruit trees	Ber, custard apple, Amla
Livestock	Tellicherry goats (5 female + one male)

System	Net income (Rs/ha/Year)	Per day income (Rs/day)	Employment Generation (man days /year)
Crop alone	3228	9	35
IFS	10417	29	131

Black soils of Coimbatore

System	Crop + trees + goat in one ha
Crop	Sorghum + cowpea for fodder 0.2 Leucaena + Cenchrus 0.2 ha
Trees	*Acacia senegal* 0.2 ha *Prosophis cineraria* 0.2ha
Livestock	Goats in deep litter system (5 females +one male)

	Crop alone	IFS
Net income (Rs/ ha/ Year)	1919	5666
Additional income	-	3749
Employment (man day/year)	40	153
Per day profit (Rs)	2.26	15.52

e) **Red soils of Paiyur**

System	Crop + dairy
Crop	Ragi /samai /pulses
Livestock	3 cows

System	Per day income (Rs/day)
Crop alone	Rs 2.38
Crop + dairy	Rs 8.10

USE OF TOOLS, IMPLEMENTS AND MACHINERY FOR TILLAGE AND SOWING – ASSESSING THEIR EFFICIENCIES

Farm machinery and implements help in increasing the utilization of labour and increasing the area under intensive and multiple cropping. Following are the some of labour saving implements widely used in rainfed farming.

Improved iron plough	Bullock drawn, suitable for all types of soils, coverage is 0.5 ha/day
Chisel plough	Deep tillage upto a depth of 40 cm is possible. The coverage is 0.42 ha/hr, when operated at a spacing of 1.5 m between rows
Power tiller operated basin lister	Alternate furrows and ridges are formed. The size of the basin formed is 120 x 30 x 15 cm. The distance between the basins is 45 cm. The coverage is 0.25 ha/day
Combined tillage bed furrow former	Combination of primary and secondary tillage operations ensures timeliness in seedbed preparation. It is a tractor drawn implement. Cost of operation is 47 per cent less and energy consumption is less by 39 per cent compared to that of mould board ploughing followed by cultivator tilling

Improved iron plough: This is a bullock drawn improved iron plough made of mild steel except the pole shaft. As and when the share wears off, it can be pushed forward. Pole shaft angle and height of handle can be adjusted according to field requirements. The plough is provided with a mould optional attachment for soil inversion. The improved iron plough is suitable for dry ploughing in all type of soil. A pair of bullocks can operate it. It can cover an area of 0.5 ha per day.

Chisel plough: Deep tillage using chisel plough is essential for improving the yield of crop especially under dry farming. Deep tillage shatters compact sub soil layers and aids in better infiltration and storage of rainwater in the crop root zone. The improved soil structure also results in better development of root system and the yield of crops and their drought tolerance is also improved. Summer fallow ploughing using chisel plough prepares the field for better uptake of rainwater and soil erosion is minimized. Deep tillage requires high draft requirement especially when the soil is dry and in a state most favourable for chiseling. The cost of the implement is Rs.5000. Cost of chiseling using this implement is Rs.265/ha.

Line sowing or drill sowing: Sowing crops in lines parallel to one another has been in vogue from very early times in Andhra Pradesh. It is done with indigenous seed drills called "gorrus". The distribution of seeds is regulated by releasing seeds in small quantities in the seed hopper with human labour. Line sowing of crops is now done with mechanical seed drills, where the distribution of seed is done by suitable contrivances.

Advantages

1. Seeds are deposited at a uniform depth enabling uniform germination.
2. Less seed rate is required.
3. Less labour is required.
4. Larger area can be sown with the drills at the appropriate season.

Disadvantages

1. The seed drills can be used only when the soil is in a good friable condition
2. Clear weather is required before sowing can be taken up.

Bullock drawn seed planter: The implement can be hitched to a pair of animals easily as in the case of country plough. The cost of the unit is Rs. 3500. It is useful for line sowing of crops like groundnut, sorghum, cowpea, Bengal gram, green gram and black gram. The capacity of the unit is 1 ha / day. The seed planter is suitable for rainfed areas where sowing is to be completed with in a short period.

Tractor drawn seed planter: It is tractor drawn equipment used for line sowing of crops like groundnut, sorghum, maize and pulses. Seed boxes along with cup feed type seed metering mechanism are mounted on the cultivator frame and the seeds are dropped in furrows opened by the cultivator shovels. Detachable side wings are fixed to the existing shovel type furrow openers of the cultivator, which, helps in placing the seed at the required depth. Coverage of the unit is 4 ha/day.

Power tiller operated basin lister : Listing is the process of formation of alternate furrows and ridges on land to conserve soil and moisture. Hence a basin lister has been developed for use with power tillers in dry farming. The principle of operation of the equipment is that the basin listing is done by lifting the furrower through a cam and follower arrangement. The cam is mounted to the power tiller wheel axle and oscillates; the 'U' shaped follower frame hinged at the front of the power tiller chassis on both the sides. For uniform penetration, a dead weight box is also attached to cam follower frame. The size of the basin formed is 120 x 30 x 15 cm and the coverage is 0.25 ha per day. The distance between the basins is 45 cm. The cost of the unit is Rs.4,000. The salient features include simple and easy to mount and dismantle; aids in conservation of soil moisture at deeper depths for better plant growth and increases the crop yield by 150 kg/ha.

Combined tillage bed furrow former

The concept of reduced tillage is becoming importance to eliminate the effect of compaction due to repeated operations in the soil. With a view to combine the primary and secondary tillage operations, to utilize the negative draft produced by the rotary tools and to conserve moisture by forming furrows, a combination tillage bed furrow former was developed which ensures timeliness in seed bed preparation

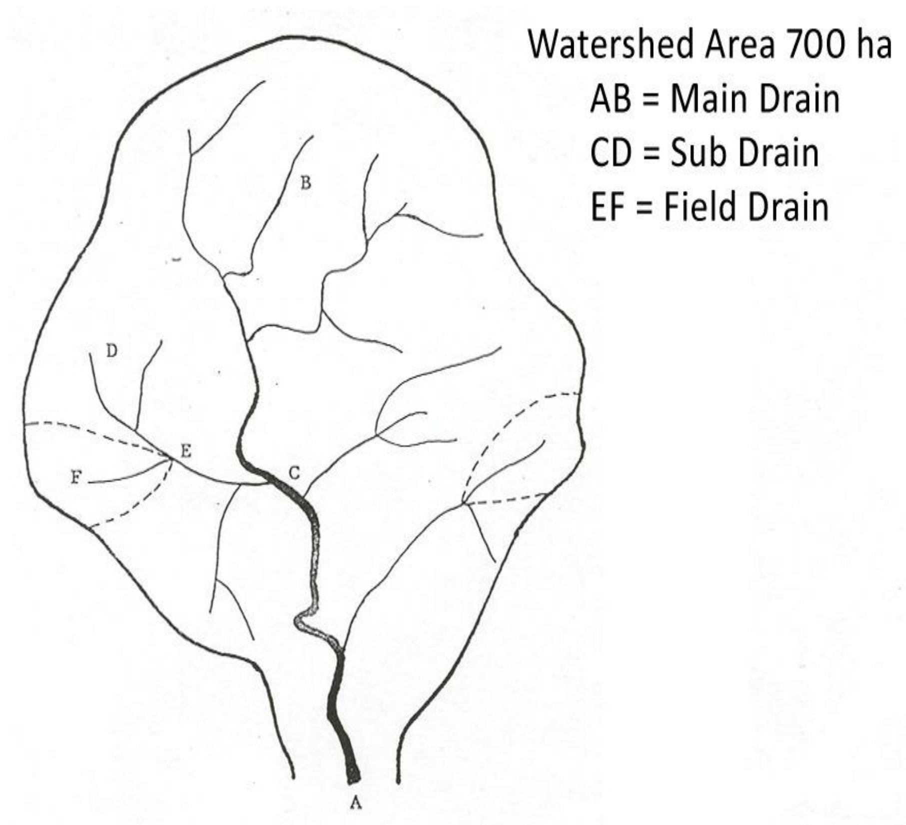
The performance of the developed unit was evaluated in black clay loam and red loam soils. The performance was compared with mould board plough + cultivator, mould plough + cultivator + disc harrow, mould board plough + power tiller for tillage operations. The percentage of fine soil particles of less than 3.5 mm were more in the combination tillage bed furrow former treatment. It was 43.5 per cent in black clay loam and 52.5 per cent in red loam soil. The bulk density was minimum in the plots tilled with combination tillage bed furrow former. It was 15.4 and 20.1 per cent less in black clay loam and red loam soils respectively when compared to mould board plough + cultivator treatment. The tillage with combination tillage bed furrow former induced a better infiltration rate when compared to other treatments. With the combination tillage bed furrow former, the cost of operation is 47.22 per cent less and the energy consumption is 39 per cent less.

Tractor drawn basin lister: The basin lister consists of three trenchers of width 30 cm, cams, camshaft, cam follower, ground wheels and frame. The penetrating portion of the trencher bottoms is provided with a replaceable share point. The cams lift each trencher fitted with a cam follower up at equal intervals. The cams are mounted on a common axle at 120 degree difference and supported by ground wheels. The power to rotate the cam is transmitted from one of the ground wheels. To reduce wheel slippage, spring tension has been provided. The basin lister unit is attached to the standard nine tyned cultivator. The seed box along with cup feed type seed metering mechanism is mounted on the cultivator frame and the seeds are dropped in between the basins. Seeds are sown in 4 rows at 45 cm apart. Power to operate the seed metering discs is taken from the ground wheel through a clutch. Changing the sprockets provided in the metering shaft can change the seed to seed distance. The operator can stop the dropping of the seeds by disengaging the clutch provided.

Broad bed former cum seeder: The same implement can be used to form broad beds separated by furrows by removing the basin lister attachment from the cultivator. The unit consists of two sheet metal floats fixed on both sides of the cultivator tynes to form the broad beds separated by furrows at intervals of 180 cm. The salient features include the basins/ broad beds and furrows formed at regular intervals prior to the sowing of crop in dry farming conserve adequate soil moisture for the utilization of crop at its critical stages; increased moisture retention of 10 per cent is achieved; significant increase in yield is observed in both main and inter crop; an area of 3.5 ha can be covered per day. The cost of the unit is Rs. 15000 (without cultivator).

Lecture 12: watershed: definition, principles, classification and management

Watershed is defined as a natural hydrological unit that covers a specific land surface area from which runoff passes through a common outlet. In simple terms, it implies a catchments or drainage basin from which water drains towards a single channel. It may extend over a few acres only or may cover thousands of acres.



Watershed development approach aims at developing the entire area in the watershed including the cultivated and uncultivated area. It is therefore different from individual farm as unit for development.

Watershed management is the integration of technology within the natural boundaries of a drainage area for optimum development of land water and plant resources to meet the basic minimum needs of the people in a sustained manner.

It is also defined as the development and management of watershed resources in such a manner as to achieve optimum production without deterioration of resources base or disturbing the ecological balance. It is termed as "**Resource centered technology**" since it helps in assessment augmentation and optimal utilisation of all the natural resources of land water and vegetation, it prevents deterioration of resources and at the same time ensures sustained productivity of land to meet basic needs of people.

Need and advantages

1. Watershed is an acceptable basic hydrological unit of planning for optimum use and conservation of soil and water resources.
2. Here, development is not confined to agricultural land alone but covers the whole land area starting from the highest point of the watershed (ridge line) to the lower most point of outlet into, the natural drainage stream at the bottom of the slope. It means every part of land including barren, sloppy and marginal lands being treated according to its capability. By adopting watershed as unit for development, different measures are adopted and executed in each of the topo-sequence according to its capability, providing an integrated treatment of arable and non arable lands.

Eg.

Ridge line	Tree culture
Marginal land	Agroforestry, pasture
Arable land	Integrated soil and moisture conservation and cropping

3. It aims at comprehensive development of all resources in the watershed i.e., holistic. It starts from the most important resources viz., soil and water and extends to other resources like crops trees, livestock etc.
4. Some of the resource conservation measures may have to be carried out cutting across field boundaries E.g. Contour bunding, contour vegetative barriers, shelter belts, drainage channel.

5. It is a multidisciplinary approach involving scientists from all related disciplines of Agronomy, Engineering, Horticulture, Forestry, Soil Science, Extension, Economics, etc.,
6. It provides for involvement of farmers in planning execution and monitoring of the development.

Classification of watershed

Based on the size the watersheds may be classified as,

Micro watersheds: The size of the watershed range from few hectares to hundreds of hectares.

These can be designed within the crop fields.

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

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

Principles of watershed management

The main principles of watershed management based on resource conservation, resource generation and resource utilization, are:

(i) Utilizing the land according to its capability;
(ii) Protecting productive top soil;
(iii) Reducing siltation hazards in storage tanks and reservoirs and lower fertile lands;
(iv) Maintaining adequate vegetation cover on soil surface throughout the year,
(v) In-situ conservation of rain water,
(vi) Safe diversion of excess water to storage points through vegetative waterways;
(vii) Stabilization of gullies by providing checks at specified intervals and thereby increasing ground water recharge;
(viii) Increasing cropping intensity and land equivalent ratio through intercropping and sequence cropping
(ix) Safe utilization of marginal lands through alternate land use systems with agriculture - horticulture - forestry - pasture systems with varied options and combinations;
(x) Water harvesting for supplemental and off-season irrigation;
(xi) Maximizing agricultural productivity per unit area per unit time and per unit of .water,
(xii) Ensuring sustainability of the ecosystem befitting the man - animal-plant-water complex;
(xiii) Maximizing the combined income from the inter related and dynamic crop - livestock tree - labour complex over years;
(xiv) Stabilizing total income and to cut down risks during aberrant weather situations;
(xv) Improving infrastructural facilities with regard to storage, transportation and marketing of the agricultural produce;
(xvi) Setting up of small scale agro4ndustries; and
(xvii) Improving the socioeconomic status of the farmers.

Objectives of watershed management

As mentioned earlier, watershed management is enshrined with the concept of sustainability meeting the needs of present population without compromising the interests of future generations. It is multi-pronged approach for steady uplift of masses living in the area. The main objectives of this multipurpose programme can be described in symbolic form by the expression: '**POWER**'. Here the letters symbolize the following:

P - Production of food -fodder - fuel - fruit - fibres - fish - milk combine on a sustained basis

Pollution control

Prevention of floods

O - Over-exploitation of resources to be minimized by controlling excessive biotic interference like overgrazing

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

Eco - system safety

Economic stabili4y

Employment generation

R - Recharge of ground water

Reduction of drought hazards

Reduction of siltation in multi - purpose reservoirs

Recreation

Components of watershed approach

1. Water -resource improvement
2. Soil and moisture conservation in cultivated lands

Hardware	Software
Permanent / Semi-permanent	Temporary/Recurring
Contour builds	Compartmental bunding
Bench terracing	Ridging after crop establishment
Conservation ditches	Contour cultivation
Land leveling	Mulching
Runoff collection structures	Vegetative barriers

3. Land treatment in non-arable lands
4. Improved cropping
5. Alternate land use system and integration of livestock in farming system.

Aims

1. Increased land productivity through improved technology
2. Sustaining the resource base thorough improved conservation measures
3. Augmentation of resource base viz soil productivity and water availability

Action plan for watershed development (Steps in watershed development)

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 watercourse and proceeding upwards to the ridge line. The area may vary as low as 100 ha to as high as 10000 ha.

2. Description of watershed. *Basic information has to be collected on,*

- Location
- Area, shape and slope
- Climate
- Soil - geology, hydrology, physical, chemical and biological properties, erosion level.
- Vegetation-native and cultivated species.
- Land capability
- Present land use pattern
- Crop pattern, cropping system and management
- Farming system adopted
- Economics of farming
- Man power resource
- Socio economic data
- Infrastructural and institutional facilities

3. Analysis of problems and identification of available solutions

4. Designing the technology components

a. Soil and moisture conservation measures

b. Run off collection, storage and recycling

c. Optimal land use and cropping system

d. Alternate land use system and farming system

e. Other land treatment measures

f. Development of livestock and other allied activities

g. Ground water recharge and augmentation

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

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

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

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

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

Organizational requirement

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

Components of watershed management programme

The main components of watershed programme are:

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

Soil and water conservation measures in watershed areas

- In situ soil moisture conservation practices
- Mechanical / Engineering measures of soil conservation
- Forestry Measures
- Agrostological Measures

Watershed Problems

a) Physical problems
b) Resource use problems
c) End problems
d) Socio economic and other problems

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

Commonly known alternate land use systems are agroforestry (agrisilviculture, silvipasture, agri-horticulture and alley cropping), tree farming and ley farming

Lecture 13: resource management under constraint situations for irrigated and rainfed farming

Resources

- Available within the farm
- Available from outside

Resource use efficiency is increased viz., light, water and nutrients are efficiently used

Soil, water and vegetation are the three important natural resources

Choice of suitable cropping system must aim at maximum and sustainable use of resources especially water and soil. Cropping systems depend on rainfall quantity, length of rainy reason and soil storage capacity.

Efficient use of natural resources for improving agriculture and allied occupations so as to improve socio- economic conditions of the local residents.

In dry areas, water is the most limiting resource for crop production than land. Maximizing the water productivity but not the yield per unit land is the better strategy for dry farming areas. Supplemental irrigation is a highly efficient practice for increasing productively of crops in arid regions. The response to supplemental irrigation varies with crops, time of irrigation, depth of irrigation, method of water application and fertilizer application.

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

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

- Soil and moisture conservation
- Integrated soil fertility management
- Inter basin transfer of surface flow which is otherwise going as waste for seas and oceans
- Creation of live storage of water by constructing reservoirs
- Integrated water management of surface and ground water sources

- On farm irrigation water management to enhance water use efficiency.

Resource management for sustainable agriculture.

Under given ecological limitation it is the rainfall variation that causes fluctuation in productivity from year to year.

- Effective utilization of stored soil moisture is important and hence crops and varieties having high Moisture Use Efficiency need to be used.

- Crop planning at per length of cropping season: Select the crop of proper duration to match the length of growing season for stabilizing in crop production.
- Instead of compartmentalizing Kharif and Rabi season Kharif-Rabi continuum seemed to be more effective with high yield besides fertility maintenance. Eg. Deccan rabi dry farming tract Bajra + Pigeon Pea better compared to cereal or keeping land fallow in Kharif.

- Relative contribution of production parameters critical inputs against full package which affect the productivity considerable experiment results indicated fertilizer application contributed 43 to 81 % increased yield for cereals. Plant density and spacing and change of variety can also bring substantial increase in production.

- Alley cropping for fertility maintenance subabul green matter incorporation increased sorghum yield by 73%.

- Contingent crop planning for weather abbreviation to avoid total crop failure and this will help us to get something to sustain.

- Soil and moisture conservation practices

Irrigated Agriculture

Measures to reduce main field duration

- Short duration varieties
- Raising nursery and transplanting
- Hastening the maturity of crops
- Paraquat spray in cotton-boll bursting
- NaCl in rice-maturity is rapid
- Ripeners (Mont 8000) in surgarcane

- Harvesting at physiological maturity

i.e. Seeds or grains will be having maximum vigour and viability but has more moisture than when the seeds are collected during normal harvest time. Similarly, in millets if harvested earlier, the fodder will be greenish.

- Relay sowing will reduce the main field duration of both crops in the sequence
- Ratooning
- Avoiding delay in maturity due to excessive vegetative growth. Eg.

Topping in cotton and growth regulator application – CCC at 40ppm

Topping and desuckering in tobacco

Reducing N supply in cereals and increasing the N supply in sugarcane will avoid delay in maturity.

Reviewing the present state of knowledge on fertilizer use in intensive cropping systems, the FAO consultation group recommended the following practices for adoption in India (FAO, 1983).

1. In irrigated rice-wheat system, N should be applied to both the crops, P only to wheat and K and Zn to rice.
2. In rice-rice-greengram/soybean system, N should be applied to both the rice crops, P dry season rice and K, S and Zn to the second crop.
3. In rainfed rice-pulse system, fertilizers should be applied to rice only. If moisture conditions are favourable, required P_2O_5 may be applied to pulse.
4. In maize + pulse intercropping system, N should be applied to maize, P to both the crops and K, S and Zn to maize, if needed.
5. In sorghum-based intercropping systems, only sorghum should be fertilised.
6. Inclusion of legumes in the cropping systems and blue-green algae/azolla in rice culture contributes 20-40 kg N/ha.

Water management has to be studied with reference to

i. Total water requirement
ii. Scheduling of irrigation

Ways and means to overcome the labour peaks are

- Allow willing labourers to do extra time work and pay extra wages.
- Use of uncertain seasonal labour force. Eg. Engaging school students for flower picking, stripping / shelling groundnut pods.
    - Adopt contract system of work. Payments are made on quantity of work turned out; again the problem is quality of work.
    - By changing the cropping pattern, the sequence of crop should allow long

distribution of labourers, without peaks and snags. There are certain crops for which season is not so rigid Eg. Sunflower - day neutral plant.

- Drawing of calendar of labour requirement and labour availability
- Carrying out of the less important operations during slack period Eg. Paddy harvest, thrashing, winnowing and cleaning, staking paddy straw and winnowing of dried paddy.

Tips for efficient labour management

- Motivate the labourers by appreciation
- Clear communication with crystal clear instructions
- Try to fulfill their physical needs like shelter, food and clothing
- Provide safety and security with better care and affection
- Protect the self esteem of the labourers and also the achievement

The pest and disease management strategy include

- Choice of resistant varieties
- Careful combination of crops in intercrop
- Careful combination of crops in sequential crop
- Destruction of crop residues
- Cultural operation for pest and disease control
- Optimum time of sowing
- Judicious use of selective pesticide

Management of cropping systems must aim at increasing the complementary interactions and minimizing the competitive interactions between the component crops so that the overall productivity of the system does not suffer.

Weed management in sequential cropping requires a proper combination of cultural and chemical methods, proper choice of herbicide and its quality are necessary. An integrated weed management based on cropping system approach has to be developed for different sequential cropping system.

i. Off season tillage with proper intercultural methods
ii. Necessary weed management techniques.
iii. Usage of herbicide with little or no residual effect.
iv. Manual/mechanical weeding after the pre-emergence herbicide.

Ideotypes for dry land farming

1. Short growth duration
2. Effective root system
3. Drought tolerance
4. High yield potentiality with altered morphology viz.,
    a. Plant with few leaves just sufficient to maintain photosyntheic output and growth (to minimise the use of water)
    b. Leaves horizontally disposed for better light interception contrary to vertically disposed most effective under irrigated conditions.

Scope for fertilizer use in dry lands

- Introduction of new high yielding varieties / hybrids in different crops which are fertilizer responsive at a given adequate soil moisture storage level.
- Development of new in situ soil moisture conservation methods enhances the duration time and depth of soil moisture availability. This will increase the fertilizer use efficiency. Hence there is good scope for fertilizer applications.
- Use of integrated nutrient management in different crops, increase the use efficiency of fertilizer and increase the yield.
- Short duration / early duration varieties of crops utilize the fertilizers efficiency than long duration varieties of the same crops.

The reasons attributed by farmers for poor adoption of nutrient supply to rain fed crops include the followings,

- High cost, inadequate availability of fertilizers and inadequate availability plus high cost of transport of organic manures, fear of scorching due to inorganic fertilizer addition.
- Low and uncertain yield and income due to undependable rainfall behaviour
- Apprehension that a well fertilized crop growing vigorously would exhaust soil moisture supply early and subject the crop to moisture stress at later stages
- Adoption of fertilizer non responsive varieties in large

Due to the above reasons, nutrient supply in drylands is at a slow pace. In order to ensure adequate nutrient supply, care must be taken to understand the factors that influence nutrient use efficiency in dry crops and to evolve an integrated nutrient management system that will be efficient, economical and environmentally sustainable.

Factors influencing nutrient use efficiency in dry lands

Nutrient use efficiency refers to the yields per kg of nutrient applied. The response of rain fed crops to nutrient application depends on crop and variety, rainfall and soil moisture availability, soil properties, quantity, time and methods of nutrient application, cropping system adopted and management practices such as moisture conservation, timely weed control etc.

a) Rainfall and soil moisture availability: Water and nutrients interact positively and exhibit a mutual complementary effect. Adequate and well distributed rainfall enables higher nutrient uptake and response. This is accomplished through greater mobility of nutrients in a moist soil, improved microbial activity and better root growth. Under moisture stress nutrient uptake suffers due to reduced mobility of nutrients, restricted root growth high salt concentration of soil solution, nutrient fixation and reduced microbial activity.

Nutrient supply improves water use efficiency through, extensive root growth reduced evaporation loss through canopy coverage of soil and higher yield.

b) Crop and variety: Crops and varieties vary in their ability to use applied nutrients. Hybrids and high yielding varieties (HYV) respond better than local varieties because of their high yield potential at the same level of resource supply.

Among the crops also, response to individual nutrients varies with species. Cereals and millets respond more to nitrogen, legumes to phosphorus and oilseeds to N, P and K.

c) Soil properties: Soil physical properties influence crop response mainly by affecting soil moisture availability. Soil nutrient status also has a significant effect on crop response, Drylands are mostly deficient in N and so there is universal response to N. Response to P depends on fixation in soil and to K on leaching loss.

d) Management practices: Nutrient management aspects such as quantity, time and method of application of nutrients, inclusion of legumes in cropping system, soil moisture conservation practices etc. also influence crop response to nutrients.

Low cost technology and non-monetary inputs in soil fertility management

Nutrient supply is a costly input, compared with other components of dryland technology package. Considering the uncertainty and low level of returns in drylands during years of abnormal rainfall, low cost technologies and non-monetary inputs relevant to soil fertility management must be given due importance. Seed inoculation and soil application of biofertilizers, use of enriched FYM, split application of N fertilizer, suitable method of application, choice of responsive cultivars and inclusion of legumes in intercropping are useful technologies in this regard.

Lecture 14 & 15: cost reduction strategies in crop production – cropping system, integrated farming system and dry farming non-monetary inputs and low cost technologies for crop production

Cost reduction in crop production

Improvement in management practices help to realize higher yields but at the same time most of the production technologies are also input intensive and labour intensive. Costs of labour and input are higher and are increasing in upward trend at very frequent intervals. Increase in wages and inputs make farmers to lose their interest for achieving higher yields. Therefore the motivation of the farmers to aim for higher productivity may be reduced if the profits are going to remain the same or sometimes less because of higher cost of cultivation. So, it is necessary to sustain higher yield levels at reasonable cost of cultivation.

In most of the crops, out of total cost of production, about 50-60% goes as labour wages and about 40 to 50% for inputs.

Out of 100% total cost of cultivation in rice, human labour occupies 40 %. The remaining are bullock pair - 7 %, seeds - 8 %, fertilizers - 26 %, pesticides - 5 % and irrigation - 12 %.

Any attempt to reduce the cost should not result in reduced yields. Cost reduction in crop production can be achieved through

a. Improving the labour efficiency and reducing the cost of labour for various operations.

Eg. 1. Ridge formation for cane (40 men labour) - **Rs. 4000**

2. Ridge plough ($2^1/_2$ pairs) - Rs. 1000

Rectification (10 labour) - Rs. 1000

Total - **Rs. 2000**

b. Reducing the levels of inputs used without affecting the yield

Eg. Neem cake coated urea for rice there by nitrogen use efficiency is increased with reduction in N requirement

c. Adoption of low – cost technology

Eg. Use of biofertilizer like azospirillum for cereals, millets, cotton, sesame and rhizobium for pulses

d. Proper management of non-monetary inputs or no cost technology

No cost technology or non monetary inputs: Non monetary inputs are defined as those cultural operations which help to achieve high yield at no extra cost and whose cost does not change with the level of output. All timely field operations from sowing to harvest are no cost technologies.

The following are the some of the no cost technologies / non-monetary inputs in the crop production

i. Selection of suitable varieties according to the region, season, soils etc.
   a. Low temperature – MDU 2 rice
   b. Saline soil – CO 43 rice

ii. Use of quality seeds without admixtures to avoid gap filling

iii. Timely land leveling and shaping for efficient water and nutrient management in garden and dry land regions

iv. Optimum time of sowing / planting. Eg. Sowing of cotton during August 15th and turmeric – end of May

v. Optimum plant population. Eg. Soybean 3.33 lakhs / ha

vi. Optimal depth of sowing / planting.
Eg. Rice 4-5 cm, ragi 2-3 cm, sorghum 3-4 cm, cotton, maize, groundnut 5-7 cm.

vii. Correct age of seedlings for transplanting (aged seedling should be avoided)
Eg. Ragi / cumbu / sorghum 16-18 days
Paddy short duration varieties – 21 days
Paddy medium / long duration varieties – 30 days

viii. Timeliness in important field operations.
Eg. Weeding during the critical crop weed competition period
Rice 10-40 days after transplanting
Maize 10-35 Days after sowing
Sugarcane 21-90 days after planting
Early weeding reduces the labour cost

ix. Irrigation at proper time and at optimum level to avoid stress at critical periods

x. Time of fertilizer application to coincide with peak nutrient demand period.
Eg. Sugarcane –with 90 days after planting

xi. Timely harvest to avoid harvest losses

xii. Proper drying is a common low non monetary input

xiii. Proper care in post harvest processing and storage to avoid wastages.

Low cost technology: Techniques which involve very little cost but help to achieve higher yields in crop production. These technologies are locally adaptable techniques which can bring down the cost of cultivation to a great extent.

Low Cost Technologies in Crop Production

1. Seed / Seedling treatments with plant protection chemicals, bio fertilizers, seed hardeners, etc. for pest and disease control, nutrient saving, better stand establishment and stress tolerance
2. Crop rotation and integrated farming systems
3. Bio-fertilizers for various crops
4. Seed hardening and seed treatment for convenience in sowing
5. Mulching
6. Use of machineries and implements in labour saving
7. Suitable method of land configuration and methods of irrigation for water saving
8. Fertilizer use in nursery and fertilizer application
9. Correct time and method of fertilizer application
10. Placement of fertilizer like N and also treated materials
11. Application of growth regulators / promoters
12. The use of neem leaves for storage is another low cost technology
13. Paired row cultivation of crops in micro irrigation systems

Measures for reducing labour and inputs

1. Tillage, land shaping, intercultivation
   - Minimal tillage, zero tillage, off season tillage
   - Use of labour saving implements / machinery

Eg. Ridger, bund former,

Ridger reduces the labour requirement by 60%

- With groundnut stripper 300kg / day can be stripped, whereas with women labourers, 60kg / day only can be stripped.

2. Seeds and sowing

- Seed treatment
- Seed drill

- Relay sowing and ratooning

3. Fertilizers management

- Soil test based fertilizer recommendation
- Cropping system approach
- Bio-fertilizers
- Balanced use of fertilizers
- Integrated nutrient management

4. Plant protection

- Seed treatment (Pest and disease management)
- Protection in nursery stage
- Pesticide spray at ET levels of damage
- Biological control based on crop rotation and cropping system
- Summer ploughing
- Integrated pest / disease management

5. Weed management

- Early and timely weeding
- Use of correct tools which will increase the labour efficiency
- Line sowing / planting for intercultivation
- Effective and selective herbicides with little residual effect

6. Harvest and processing

- Timeliness
- Use of machineries for harvesting, threshing, winnowing, etc.

Lecture 15. Conservation agriculture – principles, concepts and scope

Conservation Agriculture

Conservation agriculture (CA) integrates ecological management with scientific agricultural production. CA promotes minimal disturbance of soil by the soil by tillage (Zero tillage), balanced application of chemical inputs (only as required for improved soil quality and health crop and animal production) and careful management of residues and wastes. CA promotes application of fertilizers, pesticide, herbicides and fungicides in balance with crop requirements. CA methods can improve or sustain crop yield and protect and revitalize soil, biodiversity and the natural resource base. In short, CA methods enhance natural biological processes of the plant above and below the ground.

Principle of conservation agriculture

The three principles of conservation agriculture include: direct planting of crop seeds, permanent soil cover by crop residues/ cover crops and crop rotation.

1. **Direct seeding or planting**

Direct seeding involves growing crops without mechanical seedbed and with minimal soil disturbance since the harvest of the previous crop. The term direct seeding is understood in CA systems as synonymous with no till farming zero tillage, no tillage direct drilling etc., planting refers to the precise placing of large seeds (Maize and beans): where as seeding usually refers to a continuous flow of seed as in the case of small cereals (rice, wheat and barley). The equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. Ideally the seed slot is completely covered by mulch again after seeding and no loose soil should be visible on the surface. Land preparation for seeding or planting under no-tillage involves slashing of weeds, previous crop residues or cover crops; or spraying herbicides for weed control and seeding directly through the mulch. Crop residues are retained either completely or to a suitable amount to guarantee the complete soil cover and fertilizers either broadcast on the soil surface or applied during seeding.

2. Permanent soil cover

A permanent soil cover is important to: protect the soil against the deleterious effects of exposure to rain and sun; to provide the micro and macro organisms' in the soil with a constant supply of food and after the microclimate in the soil for optimal growth and development of soil organisms, including plant roots. Cover crops need to be managed before planting the main crop which can be done manually or with animal or tractor power. The effect of soil cover includes, i) improved infiltration and retention of soil moisture resulting in reduced crop water stress and increased availability of plant nutrients, ii) source of food for diverse soil life, iii) increased humus formation, iv) reduction of impact of rain drops – consequently reduction of runoff and erosion, v) soil regeneration is higher than soil degradation , vi) mitigation of temperature variation on and in the soil and vii) favorable condition for plant and root growth.

Practices

- Use of appropriate/ improved seeds of HYV as well as high residue production and good root development.
- Integrated management and reduced competition with livestock or other uses-including forage and fodder crops in the rotation.
- Use of multi-purpose cover crops – nitrogen –fixing, soil – porosity – restoring, pest repellent, etc.,
- Optimization of crop rotation in spatial, timing and economical terms.
- Targeted use of herbicides for controlling cover crop and weed development.

3. Crop rotation

Crop ration is not only necessary to offer a diverse "diet" to the soil micro organisms, but also capable of exploring different soil layers for nutrients. Nutrients leached to deeper layers and no longer available for the commercial crop can be "recycled" by the crops through rotation. Crop rotation also has an important phyto sanitary function as it prevents the carryover of crop –specific pest and diseases from one crop to next via crop residues. The effect of crop diversification are , i) higher diversity in crop production and thus in human and livestock nutrition ii) reduced risk of pest and weed infestation iii) better distribution of water and nutrients through the soil profile iv) increased nitrogen fixation and improved balance of NPK form both organic and mineral sources and v) increased humus formation.

Advantages of conservation agriculture

- The benefit of conservation agriculture can be grouped as
- Economic benefits that improve production efficiency
- Agricultural benefits that improve soil productivity
- Environmental and social benefits that make agriculture more sustainable.
    1) **Economic benefits** are i) time saving and reduction in labour requirement ii) higher efficiency – more output for a lower input and iii) reduction of cost – fuel, machinery operating cost and labour cost- fuel , machinery operating cost and labour cost.
    2) **Agronomic benefits** include i) improvement of soil productivity, ii) organic matter increases and iii) soil and water conservation.
    3) **Environmental benefits** – i) reduction in soil erosion, and thus of road, dam and hydroelectric power plant maintenance costs, ii) improvement of water quality, iii) improvement of air quality, iii) improvement of air quality and iv) biodiversity increases.

Constrains

Conservation agriculture has been successfully employed in sub humid as well as humid climates, but there are still some constrains in semiarid environments that may hinder its immediate application. Typically of these constrains are:

- Shortage of water limiting crop and residue production:
- Insufficient residues produced by the economically or socially important crops and lack of knowledge of suitable cover crops:
- Sale of preferential use of crop residues for fodder, fuel and building material:
- Inability to control livestock grazing, especially in areas where communal grazing is traditional (talent farmers are often obligated to allow the land owner's cattle to graze is residues after harvest):
- Inability to control residue consumption by termites:
- Insufficient money or credit to purchase appropriate equipment and supplies :
- Lack of knowledge of conservation agriculture by extension and research staff.

Issues

- The success of conservation agriculture in rain fed area depends on two critical elements, viz., residue retention on surface and weed control. Since residue retention are generally used as fodder in dry lands, there is need to determine the minimum residue can be retained without affecting the crop livestock system. Initially, emphasis may be given for crops whose residues are not used as fodder.
- More research on weed management under minimum tillage in a cropping system perspective.
- Identification of alternative sources of fodder for livestock to spare crop residue for conservation farming.
- Identification of critical thresholds of minimum tillage for various rainfall, soil and cropping system, such that the main objective of rain water conservation are not compromised. This will balance the need for conserving soil and capture rain water I the profile.
- In irrigated production system, identification of appropriate crop after paddy which have a quick vegetative growth so that canopy closes rapidly for effective weed control.
- Control termite in order to enhance the value of residue left on surface during long interval period between two crops.
- Farm implements needed for seeding rain fed crops under minimum tillage.

Lecture 17 alternate land use system and their merits – agroforestry systems – ifs to drylands

Uncertain rainfall, poor soil conditions and low level of management has made annual cropping of field crops a non-remunerative enterprise in many pockets of dry lands. In some instances, cropping has been given up altogether and lands remain fallow and become wastelands overgrown with unwanted vegetation. To arrest this trend and to bring back the land under economically useful vegetation, alternate land use systems such as grasslands / pastures, agroforestry and horticulture are recommended. This has become necessary for the following reasons;

a) Annual field crop production is nonviable and uneconomical in many years
b) Yield of field crops is low and fluctuates widely between years affecting stability and income
c) Continued use of the eroded and degraded lands under the present system of annual cropping may ecologically degrade the lands further affecting sustainability of the fragile eco-system in the drylands, leading to the creation of wastelands.
d) Alternate land use systems such as grasslands and tree culture are less risky, more productive and remunerative in these marginal lands. They will provide stability and sustainability.

The choice of an alternate land use system depends on the land capability. Most of the lands under dry farming tracts come under the land capability classes of III and above.

Land capability class	**Alternate land use recommended**
Class II	Dry land horticulture
Class III & IV	Agro-forestry / leyfarming
Class V	Pastures / silvipasture / tree farming
Class VI	Range lands / wood lots

Pastures and grass lands

Forage crops play an important role in dry land economy. They help to promote livestock husbandry to improve and stabilize income. Forage grasses and legumes are best suited for marginal lands and sub marginal lands, sloppy lands, eroded and degraded lands for soil and moisture conservation and for reclamation of wastelands.

Forage crops for dry lands include

Annual cereals Sorghum, maize, pearl millet
Annual legumes Cowpea, cluster beans (guar)
Perennial grasses *Cenchrus ciliaris* (Anjan or Kolukkattai grass),

	Cenchrus setigerus (black kolukkattai),
	Cenchrus glaucus (blue buffel)
	Dichanthium annulatum (marvel grass)
	Chloris gayana (Rhodes grass)
	Heteropogon contortus (spear grass)
Annual grass	*Pennisetum pedicellatum* (Deenanath grass).
Perennial legumes	*Stylosanthes hamata, Stylosanhes scabra* (Stylo or muyal masal)
	Macroptilium atropurpureum (siratro)
	Clitoria ternatea (sangupuspham)
	Desmanthus virgatus (Hedge lucerne / velimassal)
	Leuceana leucocephala (subapul), berseem.

Forage crops can be introduced into the dry land farming system through any of the following ways:

a) **Grasslands** or pasture with perennial grasses and legumes for grazing by livestock, cutting and stall feeding, (cut and carry system.) and hay or silage making

b) **Strip cropping** with alternate strips of grasses / legumes and annual crops

c) **Ley farming** where in perennial forage crops are grown in rotation with annual crops in 4-5 year cycle Eg. *Stylosanthes hamata* (3 years) – sorghum (1 year) – castor (1 year)

Ley farming offers the following advantages

- Provision of fodder for cattle
- Low risk system
- Soil and moisture conservation
- Enrichment of soil fertility
- Prevention of soil compaction
- Control of perennial weeds

Silviculture: Silviculture refers to the raising of trees. When trees are introduced into farms along with field crops it is known agrisilviculture or agroforestry system. Tress provides many benefits to mankind. They play protective role by making available a variety of products for human consumption, for livestock and for industrial raw material needs. Eg: Fruits, nuts, fuel, fodder, timber, wood, wax, resin, etc. They also play a protective role through soil and moisture conservation, enrichment of soil fertility through nutrient recycling and protection of environment.

Methods of tree cultivation

a) Block culture: Large contiguous area is planted with selected species of tress suitable for fuel, timber, wood or industrial use (multipurpose tree species). It is also known as wood lots or energy plantations when planted for fuel. Eg: Eucalyptus, Acacia, Prosophis.

b) Staggered planting: Trees are grown scattered in the field with annual crops raised in the interspaces. Multipurpose tree species suitable for fuel, fodder, wood and timber can be planted at 20-50 trees per hectare. Eg: Acacia + fodder sorghum vagai / neem + pulses / sorghum

c) Border trees: Trees can be grown along farm boundaries and field borders for economic use as well as boundary markers. Eg: Palmyrah, neem, tamarind, eucalyptus.

Different systems of tree culture

1. Agrisilviculture (Agroforestry) Trees and annual crops are raised in an intercropping system in the same field. Trees are planted at 5-8 m spacing and field crops are sown in the interspaces during rainy reason. Eg: Leucaena + Sorghum / Pearl millet / Castor / Pulses, Neem / Vagai + Fodder sorghum / Pulses

2. Silvipasture: Leguminous fodder trees are raised with fodder grasses and legumes as intercrops. Eg: Acacia + Cenchrus + Stylosanthes, Vagai / Sisoo + Cenchrus + Stylosanthes

3. Alley cropping or **hedgerow intercropping**: Annual field crops are grown in alleys formed by hedge rows of trees and shrubs. The trees or shrubs in hedge rows are cut back to short height (0.5 – 1.0 m) at sowing of annual crops with onset of rains and kept pruned during crop growing season to reduce shade effect and competition with field crops. The width of alley (space between hedges) is about 4-6 m. eg: Leucaena or Desmanthus as hedge row with sorghum, maize, pigeonpea, sunflower as intercrop. Alley cropping offers many benefits.

- Green fodder from hedge rows during dry season and food and dry fodder from annual crops during rainy season.
- Off season rainfall is utilized by hedgerow trees or shrubs
- Hedge rows check runoff and erosion when formed along contour or across slope
- Loppings and prunings from hedgerows can be used as fodder, fuel wood or for mulching.
- Yield of crops raised in the alleys is improved due to better microclimate through reduction in temperature and wind speed, increase in humidity and reduction in evapotranspiration loss

Success in alley cropping depends on alley width and height of hedge rows. Alley width of 5-6 m has been found to be effective. Low height of 45-50 cm is desirable. Usually one cutting of hedge row shrubs at the time of sowing of annual crops and subsequent prunings at monthly interval during cropping season are optimal. During dry season, cutting is done depending on fodder requirement.

4. Timber - Fibre system (TIMFIB system): It involves growing trees and perennial fibre crops together. Eg: Leucaena + agave

Choice of trees for dry lands

Trees suitable for dry lands must have the following characters

- Multipurpose tree species (fodder, fuel, timber, wood)
- Adaptable to wide variations in soil and climate
- Rapid growth
- Withstand severe pruning

Soil	Rainfall (mm)	Trees suitable
Black soil	730-830	*Euclayptus viridis, Acacia nilotica, Leucaena leucocephala*
Black soil	510-760	*Acacia nilotica, Acacia auricultiformis, Acacia indica Acacia planifrons, Leucaena leucocephala, Azadirachta indica, Ailanthus excelsa*
Red soil	570 - 830	*Leucaena leucocephala, Eucalyptus cameldulensis, Acacia auriculiformis, Acacia nilotica, Acacia senegal, Acacia holoserecia, Acacia tortilis, Albizzia lebbeck, Prosophis cineraria, Hardwickia binata, Dalbergia sisoo, Azadirachta indica*
Red soil	380 - 500	*Prosophis cineraia, Albizzia lebbeck, Acacia nilotica*
Red soil	Less than 300	*Acacia nilotica, Acacia senegal, Acacia tortilis, Zizljphus jujuba*

Land use classification (land capability classification)

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

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

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

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

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

CLASS V: these soils generally not suitable for grain crops due to limitations such as rocky soil, faded areas with any 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.