**Definition of drought:**

Drought is a climatic irregularity, characterized by deficient supply of moisture resulting either from sub-normal rainfall, unpredictable distribution, higher water need or a combination of all the factors. It is called as disaster in slow motion and the area covered is large.

If it persists over two to three years, it may lead to famine condition. It would affect various human activities and lead to problems like widespread crop failure, un-replenished ground water resources, depletion in lakes/reservoirs and shortage of drinking water and reduced fodder availability etc.

**Types of drought**

Broadly droughts have been classified into three types.

* Meteorological droughts.
* Hydrological droughts.
* Agricultural droughts.
1. **Meteorological droughts:**

A situation when there is significant decrease (> 25%) of normal rainfall over an area.

1. **Hydrological drought:**

Meteorological drought, if prolonged, will result in hydrological droughts with marked depletion of surface and ground water level.

1. **Agricultural drought:**

It occurs when both rainfall and soil moisture are inadequate during growing season to support a healthy crop.

**Drought Management:**

1. **Water conservation practices**
2. **Crop management**
3. **Water conservation practices:**

The improved moisture condition in the soil can be achieved by

1. Increasing water storage in the root zone
2. Reducing losses of moisture due to evaporation and transpiration
3. **Increasing water storage in the root zone:**

The amount of moisture stored in soil mainly determines yield level that can be expected. The amount of moisture absorbed by soil depends on

* Increasing infiltration rate
* Reducing runoff rate

In this way the amount of moisture stored in the soil can be increased.

1. **Control of runoff:**

The movement of water from one place (higher) to the other (lower) is called as runoff. It depends upon:

**Soil conservation practices:**

1. **Strip cropping:**

Grow crops in the form of strips leave fallow field after every two or four crop strips.

1. **Bund Making:**

By making bunds 6 – 12 inches around the field reduces runoff and increases infiltration.

1. **Terracing:**

Water stay in it when water level reach higher in one piece of land and then it will move down. These all practices are useful in reducing runoff and effective in increasing amount of moisture in the soil. In short all those factors which reduce the movement of water will increase the amount of water stored in the soil.

1. **Contour cultivation:**

Contour cultivation is a simple method of cultivation across the slope which effectively reduces the run off and soil loss on gentle sloping lands. In this, all field operations such as ploughing, planting and inter-cultivation are performed on the contour. It helps in reduction of runoff by impounding water in small depressions and reduces the developments of rills. Maximum effectiveness of this practice is on medium slopes and on permeable soil.

1. **Conservation furrow:**

Conservation furrow is a simple and low cost in situ soil and water conservation practice for areas with moderate slope. This practice is suitable for soils with problems of crusting, sealing and hard setting. In this system, series of furrows are opened on contour or across the slope at 1-3 m apart. The spacing between the furrows and its size can be chosen based on the rainfall, soils, crops and topography. The furrows can be made either during planting time or inter-culture operation using country plough.

Two to three passes in the same furrow may be needed to obtain the required furrow size. These furrows harvest local runoff and improve the soil moisture in the adjoining crop rows particularly during the period of water stress. This practice increases crop yields by 10-25 percent and it cost around Rs. 250-350 ha-1.To improve its effectiveness further, it is recommended to use this system along with contour cultivation or cultivation across the slope.

1. **Broadbed and furrow system:**

On black soils, the problem of water logging and water scarcity occurring during the same season are quite common. In this situation conservation practice should store water in the profile and drain excess water. The Broadbed and Furrow” (BBF) system successfully meets these goals. The BBF system consists of a relatively raised flat bed or ridge approximately 90 cm wide and shallow furrow about 30 cm wide and 15 cm deep. The BBF system is laid out on a grade of 0.4 -0.8 % for optimum performance. It is important to attain a uniform shape without sudden and sharp edges because of the need to plant rows on the shoulder of the Broadbed.

**Increasing infiltration rate in the soil:**

The maintenance of high infiltration rate is an important factor in soil because it reduces runoff and increases water management efficiency of rainfall by minimizing soil losses due to erosion. It depends on:

* **Soil Structure**Hardpan containing soils and clayey soils has less infiltration while coarser soils have more infiltration rate.
* **Plant cover:**Scattered cropping prevents sealing of the soil thus increasing more infiltration as compared to the line sowing. Row crops such as cotton, maize, sorghum etc afford less protection against effect of rainfall than do densely growing crops such as fodders and small grains like wheat, oat, barley, therefore the row crops tends to lower the infiltration rate.
* **Degree of dryness:**More the soil is dry; more will be the infiltration rate as space is more.
* **Crop Density:**
More the crop density more will be the infiltration rate as resistance to water flow will increase.
* **Intensity and Duration of Rainfall:**
Infiltration will be more when rain is less intense and occur for short duration. If rain is more intense and occur for long time, then rain water will be lost by run off.
* **Vegetative barriers:**

Vegetative barriers or vegetative hedges or live bunds are effective in reducing soil erosion and conserving moisture. In many situations, the vegetative barriers are more effective and economical than mechanical measures, viz., bunding. Vegetative barriers can be established either on contour or on moderate slope of 0.4 to 0.8 percent. In this system, the vegetative hedges act as a barrier to runoff flow and slowing down the velocity resulting in deposition of eroded sediments and increased rainwater infiltration.

It is advisable to establish vegetative hedges on small bund. This increases its effectiveness, particularly during the first few years when the hedges are not so well established. If the main purpose of the vegetative barrier is to act as a filter to trap the eroded sediments and reduce the velocity of runoff.

**Methods to increase infiltration rate**

* By Mulching
* By Improvement of Soil Structure
* Both straw mulch and crop residues significantly improve infiltration rate by reducing impact of rain drop.

**WATER HARVESTING:**

Under arid conditions reducing runoff or increasing infiltration rate are ineffective when amount of moisture does not sufficient for crop production.

An water harvest efforts should be made in opposite direction i.e., to increase runoff and reduce infiltration in certain areas which can serve as source of water supply for other areas thus water harvesting means using water derived from collection of runoff and supplement moisture. Water in adjacent areas situated at lower elevation (level) water collected from the upper levels (called donor areas) and then that spreading water in adjoining area called recipient areas.

**MICRO WATER SHEDS:**

In this system runoff water from various parts of a field is collected in strips where crops are grown. The crop is sown in narrow strips between wide intervals. Relative width of water shed strip and of crop producing strip depend on the amount of annual rainfall the usual ration varies from 2:1 to 4:1. e.g. if rainfall is low you can grow 2 strips of row crops.

Different methods or increasing runoff water from water supplying strips are:

1. Use of plastic films, rubber or metal sheets.
2. Stabilizing the soil surface by spraying materials to reduce infiltration rate e.g. using sodium carbonate @ 45 Kg/ha may enhance 70 % runoff from clay loam soil.

However main disadvantages of all these materials are:

* Their high cost
* Susceptibility to wind damage.

 **CONSERVATION BENCH TERRACES:**

A terrace not only reduces water erosion but also suppressed runoff water over a leveled bench where it is absorbed in the soil for crop use. This method is useful provided bench where it is absorbed in the soil for crop use. This method is useful provided.

* Precision land leveling is carried out.
* Adequate terrace outlets to handle excess water
* Fertilizers may be applied for efficient use of water.

It is recommended to use 1/3 of field area for terrace establishment and remaining 2/3 for water shed area under average rainfall conditions.

**Farm ponds:**

Farm ponds are very age old practice of harvesting runoff water in India. These are constructed by excavating soil from a low lying area of the field. Following guidelines are to be followed in design and construction of farm ponds.

High-storage efficiency (ratio of volume of water storage to excavation) can be achieved by locating the pond in a gully, depression, or on land having steep slopes. Whenever possible, use the raised inlet system to capture runoff water from the upstream. This design will considerably improve the storage efficiency of the structure.

Seepage losses can be minimized by selecting the pond site having sub soils with low saturated hydraulic conductivity. As a rough guide, the silt and clay content of the least conducting soil layer is inversely linked with seepage losses. Therefore, it is best to select the site having subsoil with higher clay and silt and less coarse sand. Also, reduce the pond wetted surface area in relation to water storage volume. This can be achieved by making the pond of a circular shape or close to circular shape. Evaporation losses can be minimized, if the ponds are made deeper but with acceptable storage efficiency to reduce water surface exposure and to use smaller land area under the pond.

**B) Reducing evaporation losses:**

1. **Soil mulch:**

A surface mulch of dry soil about 5-8cm deep will obstruct the rise of water to surface and thus effectively reduces loss of water then a soil having undesirable surface/layer. An important benefit from this practice may be obtained on soil that shrinks and crack deeply after drying e.g. evaporation from cracks in clay soils 30-90% of that a comparable area of surface soil.

1. **Straw mulch:**

Straw and crop reduces left on the soil surface or also effective in reducing evaporation. Generally straw mulch decreases both the amount of the energy absorbed by the soil. And air movement above the soil and thus evaporation is reduced. Straw mulch can save 50-75mm of evaporation under dry condition.

1. **Chemical treatment:**

Use long chain alcohol (hexadecanol) mixed with soil surface may reduce evaporation by 43%.

1. **Decreasing transpirational losses:**
* Increasing leaf resistance to water loss by applying material that tends to close/over the stomata by use of anti transpirant
* Reducing the net energy uptake by the leaves through increased leaf reflectants.
* Reduction of shoot growth by retardants e.g. CCC. 2-chloroethyl trimethyl ammonium chloride.
* **Use of wind breaks:**

Wind breaks reduce the load of sensible heat from dry surroundings and crop yield may increase by 20-30% those areas where no wind breaks are used.

1. **Crop Management:**
* Dry farming
* Fertilize use in different areas
* Planting date
* Plant population
* Crop rotation
* Cropping pattern
* Drought management at different crop stages
* Tillage

**Dry farming:**

It is the practice of successfully growing of crops without artificial irrigation the success or failure of cropping mostly depends upon conservation of rain water in the soil. In pun jab, the dry land farming is practiced in Gujrat, Sialkot, Jehlam, Chakwal, Rawalpindi, Attock, Mianwali etc.

 The important consideration is being kept in view for dry land farming are

* Selection of drought resistance varieties
* Conservation of rain water by proper cultivation techniques.
* Proper rotation of crops.

To fulfill the above principles, following measures should be adopted:

1. **Bund Making:**

The larger land area should be divided into small level plants through strong bunds the height of bunds should be 12-16 inches depending upon type of soil. The main advantage of this practice would be to save the loss of water from runoff and consequently increase infiltration of water in the soil.

1. **Opening of soil:**

Soil should be ploughed and make loose before rain, to absorb maximum rain water. Soil should be given shallow cultivation after every rainfall to produce mulch to check the evaporation losses.

1. **Eradication of weeds:**

Weeds should be kept under control to check the losses of water by transpiration. This will also increase the fertility of soil.

1. **Proper rotation of crops:**

In dry land farming definite rotation must be followed crop such as cereals must be followed by legume crops and vice versa e.g. millet and sorghum must be followed by chick pea.

1. **Selection of variety:**

Drought resistance varieties having deep root systems and low transpiration ratio should be selected for sowing in dry areas.

1. **Fallowing and mulching of land:**

Fallow and properly mulch lands, free from weeds can control moisture and this water can be used for rising of crops in the next season.

1. **Contour planting:**

Leveling of land should be done according to contour of lands. Strips of land having a similar contour should be leveled and converted into field.

1. **Proper moisture in the plough layer:**

Proper moisture will be in plough layer. If there is a deficiency of moisture in upper layer at the time of sowing it should be brought up by lower layer of soil by running ruler or heavy planking over the surface of soil. This will help in good germination of crops.

1. **Seed rate:**

Under the low moisture condition in soil (plough layer 8-10inches) low seed rate should be used. Furthermore use of pore rather than broad casting of seeds should be adopted for sowing of the crops.

**Fertilizer use in rainfed areas:**

Of total cropped area of 20 million ha, about 5million ha are rainfed. In addition 10 – 12 million ha is arid rangeland. The rainfed areas can be classified into three zones.

1. Areas where annual rain fall is sufficient (380 mm and above) to grow wheat with proper water management and conservation techniques.
2. Areas with average annual rainfall between 280 – 380 mm where only summer crops can be grown.
3. Areas with average rainfall less than 200 mm where land use to limited to grazing of small amount of forage produced.
Substantial improvement in crop yield is possible in rainfed areas receiving about 250 mm and above rainfall if proper management techniques are adopted the cropping pattern in rain fed areas is determined by rainfall distribution. Of the total rain, only about 30 % fall in winter and rest in summer months. It has been demonstrated that high yields are attain able with proper use of fertilizer. Fertilizer, therefore, plays an important role in realizing high yields of crops in rainfed areas. Under rainfed condition, the efficiency of applied fertilizer is very much influenced by the availability of soil moisture as well as improved cultivation methods and management practices.

**Water conservation measures:**Deep tillage is most desired to break the hard pan and increase the moisture absorbing and retaining capacity. Contour bunds are laid to control runoff. Where possible runoff rain water is collected and stored to be used latter for irrigation. This recycling of runoff water is part of a good management practice.

**Fertilizer application:**in the rain fed areas most of the fertilizer experiment is done on various crops show the need of N and P. the need for K is not consistent and varies with the soil fertility level responses to K is more likely to occur in the sandy soils. Efficiency of fertilizer use in the rainfed areas is much dependant on water management and cultural practices.

If the crop is raised with low rainfall, apply all the N, P and K fertilizers at planting time. Drilling the fertilizer 10 – 15 cm deep in the soil at the time of sowing using a fertilizer cum seed drill is the better way to apply the fertilizer. Application of N in split doses is recommended only in high rainfall areas.

**Improved cultural Practices:**Fertilizer use should be combined with other improved farming techniques to achieve high yield . These include planting of crops, variety and proper sowing time to enable maximum use of limited moisture. The optimum seeding rate must be used to have adequate plant population. The seed must be sown at the desired depth at the proper soil moisture conditions. Weeds should be controlled as they compete for moisture and nutrient supply. The crop should protect from attacks by pest and diseases. Finally harvesting and thinning losses should be minimized.

**Soil Moisture and its Response to fertilizer:**

Soil moisture affects the efficiency of fertilizer use in two ways:

* By improving the uptake of nutrients.
* By increasing the dry matter production.

**Effects of fertilizer on Evapotranspiration and Soil Moisture Depletion:**

The application of N increases the wheat yield and also increases the water use. The depleting of stored soil moisture was also accelerated.

Without N, soil moisture extraction was largely limited to the upper surface 91 cm but with the use of N, wheat plant extract water to double this depth. N increases the water use efficiency by 56 %.

**Relationship b/w Rainfall and Fertilizer Practice**:-

1. When rainfall is too limited for arable cropping, fertilizers are not commonly used.
2. Effects of fertilizers under varied conditions of precipitation do not predict reliable crop responses. E.g., in one season, wheat yields are increased significantly by fertilizer application; in the following season, which was much was much drier, yield increases were not found.
3. Under limited and erratic rainfall, an extremely use of fertilizer should be made. However when judiciously application, fertilizers increase utilization of the limited moisture available to plant.

**Minimum Precipitation Required**:-

Under inadequate soil moisture, crop fail to respond to fertilizers or the response may be too small to be economic. The minimum amount of rainfall needed to ensure satisfactory yield level depends on mainly factors:

* Efficiency of rainfall.
* Moisture reserves in the soil.
* Proceeding crop history.
* Temperature.
* Evaporation.

An empirical and son what arbitrary figure is 300 mm rainfall in winter rainfall regions and about 500 mm in a summer rainfall.

**Timing and Balanced Fertilizer Application:**

1. Nitrogen fertilizers stimulate only vegetative growth and thereby exhaust soil moisture supply before the period of maximum water requirement of the crop. The rapid concurrent increase in root zone development and leaf area apparently cause depletion by limited soil moisture supply early in the growing season.
2. When soil moisture is deficit, the plants fertilized with P show a greater ability to take up available moisture than these fertilized with N.
3. Generally a balanced nutrient supply is beneficial as it actually enable the crop to make more efficient use of the limited soil moisture available.
4. Water use efficiency in rain fed grain crops was increased by 27 % when application was delayed to coincide with the period of maximum requirement. Excessive vegetative development of the young crop is avoided.

 **CONCLUSION:**

1. When rainfall is insufficient to ensure a satisfactory crop, the additional yield resulting from fertilizer may be too small to be economically justified.
2. The main factor in promoting a balanced fertilizer use depend on
* To improve moisture storage.
* To moisture losses by crop rotation, improves tillage practice and chemical weed control.
1. Low availability of N and P is more seriously problem than rainfall.

**PLANTING DATE:**

In arid and semi arid regions choice of an appropriate planting date has a considerable effect on water use in relation to economic yield by ensuring that the pattern of growth is adjusted to the pattern of rainfall or to available soil moisture.

PET

R.F

C1

C2

B2

B1

A2

A1

Nov

Oct

Sep

Aug

July

June

May

April

Mar

Feb

Post Humid Period

Humid Period

Pre Humid Period

Rainy Season

A1= Beginning of rainy season

A2 = Beginning of transition period (where precipitation is generally to half of PET).

B1 = (Middle of March) End of transition Period and beginning of humid period

B2 = About in early September end of humid period.

C1 = (Toward end of October) end of rainy season

C2 = Exhaustion of moisture reserve in soil

1. **PREHUMID PERIOD:**
During this period, rainfall is significantly less to potential evapotranspiration. The period begins with the first rain (point A1) and ends when precipitation equal to PET (point B2) this period is rarely the time for sowing in dry soils when it proceed the first affective rainfall are in a moist soil if usually early rains occur.

Sowing in dry soils, of course, involves the risk to cause the germination failure and subsequent growth under such conditions only crops that can affectively withstand desiccation between beginning of germination and full emergence. This risk involves in dry sowing is justified by possibility of increased yield, due to longer growing season and move affective use of rainfall early in the season.

When the risk of sowing in dry soils is too great and hard for tillage operation, the pre humid period is mostly devoted to seed bed preparation. These tillage operations in this case become easier as one approaches point B1.

1. **The humid period:**

In this period, the total precipitation is in excess of PET. This humid period does not coincide with the rainy season i.e. it begins later and ends earlier. During this period the excess of rainfall is generally stored in the soil under ideal management practices. The entire root zone is saturated to field capacity and ideal moisture conditions for crop production especially for crop maturation during the third point in to C1 will prevail.

Relative position of B2 period and date of flowering or earing in cereals have a considerable impact on potential yields. The longer the humid period, the greater will be prospects for the maturation under favorable conditions of rainfall and moisture, the danger of epidemic diseases is also high.

1. **Post humid period:**

This is the period in which total rainfall is less than PET at the end of rainy season, actual evapotranspiration continues until the reserves of moisture in the soil are exhausted. The date of sowing may affect crop yield and water use efficiency. Early planting under conditions of limited moisture supply may increase grain yield as a result of more favorable seasonal water use distribution e.g. carrier to heading early planted sorghum may use the amount of water as compared to late sown.

**Plant population:**

The number of plants requires per unit area to achieve highest yield will depend on nature of crop and it environment this number cannot be too small, or can it be too large. Maximum exploitation of the factors needed for growth is achieved only when plant population exercises maximum pressure on all the production factors as result the individual plants are under relatively severe stress because of inter plant competition.

The relation of economic yield to density is different from that of total dry matter production in to biological yield. If biological yield production rises with increasing density to a maximum which then remain constant into but in some cases it may decrease at a very high plant population level. At this density increase in total dry matter yield per unit area due to additional numbers of plants is offset by an equal laws in weight per plant

The relationship of grain yield to population is different as plant density increases, the yield of grains increases to a maximum which remains constant with certain population range and the decline more or less steeply as population increases, even when moisture and nutrients are not limiting.

**Interrelation ship between population and factors affecting yield:**

1. **Moisture supply:**

The basic principle is that the optimum density of crop should be lower than normal under condition of limited soil moisture.

1. **Nutrients availability:**

At highest levels of nutrients supply, more plants per unit area are required to produce maximum yield as plant density increases up to a certain limit; a crop will continue to respond to higher levels of added nutrients provided moisture supply is adequate. At low levels of nutrients supply, dance population has adverse affect on crop yield.

**Disadvantage of dense population:**

1. **Plant height:**

With the increase in crop density, the height of plant increases instead of lateral spread.

1. **Lodging:**

Crop stems are thinner and due to more height, crop is more subjected to lodging.

1. **Plant morality:**

In very dance crop, there is a competition among plants result in morality of some plants.

1. **Disease resistance:**

In more closely sown crop, there is a rapid spread of diseases.

1. **Maturity:**

Maturity is general delayed by one day for each individual plant per square meter.

1. **Root systems:**

The extant and distribution pattern of root system are markedly influenced by plant population. Generally widely spaced plants develop a circular distribution of roots and in high densities root system of individual plants interpenetrating a high degree.

**Planting pattern:**

Planting methods/ pattern has a direct effect on yield through absorption of radiant energy and on water evaporation. The common planting patterns are:

* Broadcast (irregular spacing)
* Beds
* Rectangular arrangements
* Square planting

**Crop rotation:**

It is defined as the growing of crops in an orderly and well planned way. It depends upon

* Type of crop sown
* Local economic factor
* Tradition

**Objectives of crops rotation:**

* To prevent the built up of the insects pests, weed and soil born diseases.
* To maintain soil fertility
* To control erosion
* To conserve soil moisture from on season for the next
* To ensure a balanced program of work trough out the season.

**Principles of crop rotation:**

The traditional principles on which the planting of crops rotations is based on:

* Alternative growing of crops with differential ability to absorb nutrients from the soil or having different root depths.
* Alternating crops susceptible to certain diseases with those that are resistant (alternate host provision).
* A panned succession of crops that like it to account any detrimental or beneficial effects on one crop on the following crops. These effects may be due to toxic substances, affects on nutrients supply, build up of organic matter, soil microorganisms or residual soil moisture.
* Alternating soil exhausting crops with crops that contribute to the improvement of soil fertility.
* Alternating crops with different peak requirements of labor and water etc.

The traditional crop rotations are in general exhausting and make no contribution to soil fertility. The basic problem is therefore, to device a crop rotation that will raise the level of soil fertility thus making it possible for following crop to benefit fully from the favorable moisture regime prevailing during its growing period. It is frequently assumed that pulses are desirable proceeding crops for winter cereals and it was originally that increasing the area under pulses would have a beneficial affects on soil fertility. However, results are always disappointing at harvesting. A seed from the legume usually results in a drop of at least 30% in the yield of the fallowing wheat crop as compared with following wheat with fallow.

* Legumes → Wheat → 30% loss
* Wheat → Fallow → Fallow

Leguminous crops that are not allowed to mature seed but are used for green manure, hay and silage have been shown to improving the soil fertility, when a deep rooted legume crops such as Lucerne is turned under green manure, the soil has usually dried out to a depth of several feet when the legume is cut before the seed is formed the amount of plant nutrients removed from the soil is relatively small while the soil is enriched in nitrogen and organic matter.

**Factors affecting crop rotation:**

* Climate
* Type of soil moisture
* Availability of inputs
* Availability of labor
* Situation of farm
* Size of the farm
* Types of farming

**Types of crop rotation:**

1. According to residual effect on soil
* Exhausting rotation
* Restorative rotation
1. According to period of time
* Fixed rotation
* Flexible rotation

**Cropping pattern:**

A rotation adapted to a certain climatic region is called as cropping system or cropping pattern.

1. **Subhumid areas:**

They include Rawalpindi, Kohat, Sialkot, Potohar and Gujrat in these areas cropping system depend on summer rainfall. Generally two crops are raised in two years from the same piece of land. Most rotations fallowed are wheat and sorghum. Sorghum or Millet is sown in June-July with start of rainy season. Sorghum and Millet are sown in larger part of Barani areas where maize replaces these crops to a great extent at placed where annual rainfall in 750 mm. In Sialkot and Gujrat wheat occupies more then 50% of the annual cropped area and the next important crop is gram. Lentil is also an important pulse grown in Sialkot district. About 40% of the total annual cropped area is under the Kharif crop mainly millets of which about ½ of the areas are under Kharif pulses.

Common rotations followed are:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1 | Wheat | Sorghum/Millet | Fallow  | Fallow  |
| 2 | Wheat | Summer pulses | Fallow | Fallow |
| 3 | Wheat | Fallow | Wheat | Fallow |
| 4 | Wheat | Millet | Lentil/Gram | Fallow |
| 5 | Ground nut | Fallow | Ground nut | Fallow |
| 6 | Ground nut | Fallow | Millet | Fallow |
| 7 | Maize | Fallow | Ground nut | Fallow |
| 8 | Summer pulses | Fallow | Millet | Fallow |

1. **Humid areas:**

This includes Murree hills and part of Hazara district. Cool winter restricts crop choice and growing season cultivated land has a steep which are terraced. Maize is the most important crop and occupies the largest area than other crops. Some vegetables especially potatoes occupy second position. At altitude bellow 4000 feet wheat and oat are sown after harvesting maize crop.

1. **Sami arid regions( 250-500mm annual rainfall):**

In Sami arid region having annual rainfall between 250-500 mm include the Potohar upland, salt range, Jhelum, Chakwal and some part of Rawalpindi and Fateh Jung. In these areas poor crop of wheat is raised. Rabi sowing accounts for 70-80% of annual sowing in Rawalpindi side where as in Chakwal and Fateh Jung it is 50-60%. Systematic crop rotation is rarely followed and the common practice is to sow the same crop year after year on the same piece of land. If summer rainfall is adequate and timely the area under Kharif crop increase the farmers adjust their cropping with the time and amount of summer rainfall about 80% land in winter is put under wheat gram and taramera. Millets occupies 40% of the area sown in summer and pulses such as mash and mung etc occupies remaining 10%.

1. **Arid regions( 100-250 mm annual rainfall):**

These areas are Mianwalli, Muzzafargarh, D.G Khan, salt ranges of Sargodha and some part of Thal. Millet is the common crop grown in summer because it more drought resistant than other crops. Taramera and gram are also sown in winter and in certain areas having rainfall of 250 mm otherwise area is used for grazing. Gram is the most important crop and thus occupies 80% of the winter crop area in Thal. Wheat and Barley are also grown in Northern parts of Thal. In summer, crops such as millet, guara and other pulses (mong and mash) are also sown on limited area.

**Factors affecting cropping patterns:**

* Soil type
* Climate
* Availability of irrigation water
* Types and system of farming
* Technical skill of the farmer
* Availability of labor
* Availability of inputs ( seed, fertilizers etc)
* Control of pest and diseases
* Marketing conditions
* Government policies
* Effect of competition among crops
* Special soil conditions ( water logging, salinity, eroded)
* Location of farm
* Land tenure
* Development of agro based industries
* Financial resources and credit facilities
* Social factors

**Drought management at different crop stages:**

1. ***Early Season Drought:***

Early season droughts occur due to delay in commencement of sowing rains. Sometimes, early rains may occur tempting the farmers to sow the crops followed by a long dry spell leading to withering of seedlings and poor crop establishment.

The management options to cope up with early season drought are:

* Raising community nurseries for cereal crops and transplant the seedlings with the onset of rainy season.
* Sowing of alternate crops/varieties depending upon the time of occurrence of sowing rains. The seeds may not be available to the farmers and government should provide seed through seed banks promoting seed villages.
* If there is a poor germination and inadequate plant stand, re-sowing is recommended. Seed priming helps in better crop establishment.
1. **Mid-Season Drought:**

Mid-season drought occurs due to long gaps between two successive rainy events when the moisture available in the soil falls short of water requirement of the crop during the dry period.

The management options to cope-up with the mid season droughts are:

* Harvesting and recycling of rain water for life saving irrigation.
* Reducing of crop density by thinning.
* Weed control and mulching.
* In-situ moisture conservation.
* Dust mulching, repeated harrowing.
* Use of anti-transparents.
1. **Late Season Drought:**

If the crop encounters moisture stress during the reproductive stage due to early cessation of rainy season, there may be rise in temperature, hastening the process of crop maturity. The grain yield of crops is highly correlated with the water availability during the reproductive stage of growth. Short duration high yielding varieties may escape late season droughts. Another possibility is to provide supplemental irrigation from harvested rainwater. Organic mulches are found to be useful in improving crop yields during post-rainy season. When crops are sown late, terminal drought can be anticipated with greater certainty. Therefore, varieties that respond better to terminal droughts have to be preferred.

**Tillage:**

Tillage is the manipulation of soil for satisfactory planting, germination, growth and yield of crop.

The affect of tillage methods on crop growth and yields are to a larger degree attributable to an increased soil moisture reserves.

* By creating soil conditions that favors root growth and penetration
* By improving infiltration and conservation of water

**Objectives of tillage:**

1. **Improvement of soil moisture:**

Tillage operation carried out under conditions of optimal soil moisture cause minimum damage to soil structure by compaction. The pressure exerted by tillage equipments may even increase aggregation. However any beneficial effect may be easily lost by subsequent tillage operations if carried out in dry soils, these operations reduce a large proportion of the aggregates in to fine dust, if the soil is wet, compaction and reduced pore space results.

1. **Moisture conservation:**

The effects of tillage method on crop growth and yield area to a large degree attributable to differences in soil moisture regimes which in term are due to improved infiltration and conservation of water. Tillage can be effective in reducing surface runoff if it is carried out according to improved soil conservation practices. Rough surfaces induced by tillage can increase infiltration of water into the soil by minimizing crust formation. These effects can be further enhanced by a mulch of crop residues which protects the soil from rain drop impact.

1. **Soil drying:**

The alternate drying and rewetting the soil has a marked beneficial effect on soil fertility. Complete drying out to a considerable depth can be achieved by growing a crop that reaches maturity during the dry season, followed by a deep ploughing that turns up hard clods that are then thoroughly baked in sun. These clods break down subsequently, thereby restoring the soil moisture.

1. **Soil permeability:**

The heavy equipment cause soil compaction and thereby adversely effects water penetration. This is accompanied by reduced root development and plant growth. In order to improve water infiltration, compact layer must be eliminated. This is achieved by tillage equipments which shatters the soil below the compacted zone.

1. **Root penetration:**

Tillage usually affects only 1/10th of the soil volume in which the root system of the most crops develops, and therefore, has only a limited effect on root penetration. A plentiful supply of nutrients and soil moisture at lower soil level is more effective in promoting deep root penetration then tillage operation unless a hardpan is present. In this case, it is breaking up by ploughing or sub soiling is essential in order to improve root penetration.

1. **Seed bed preparation:**

The basic function of soil tillage is to prepare a seed bed and to cover the seeds an initial ploughing is not particularly effective in this respect a number of additional operations are usually needed to offset some of the negative effects of the ploughing.

1. **Soil inversion:**

Under certain circumstances, soil inversion may be a desirable objective. It may bring to the surface fertile soil with good structure covering the top layer that has lost its structure and is poor in nutrients. It may help soils sanitation by a through burying of crop residues which may carry insect at various stages of development or the spores of plant pathogens.

1. **Weed control:**

Weed control is the most beneficial and universal rule of tillage with proper timing, it is possible to control weeds efficiently and economically when they are small, by using light equipment for cultivation, deep ploughing carried out during the summer months in dry soils, is probably the most effective means of controlling perennial weeds such as Johnson grass or Couch grass. The best system of tillage is, therefore, the one that accomplish these objectives with the least expenditure of labor and power.

The farmers tend to accomplish all these objectives by cultivating the land frequently with the existing wooden plough this implement is no reliable because

* It goes through a depth of about 7.5-10 cm and open and exposes the moisture upper soil to air and heat, resulting in considerable loss of moisture which may be detrimental for seed germination.
* This implement does not kill or burry the weed properly.
* The wooden plough cannot go deeper to break hardpan

When the advent of modern equipments, and entirely new concept of tillage method developed in dry regions which are different from that of traditional tillage in arid zones. For these reasons, different types of implements have been developed and are being used in the rainfed areas of the world.

**Chisel plough (subsoiler):**

They are used for breaking the plough (hard) pan and this should be done occasionally i.e. only once a year. The objective of subsoiler is to fill the slots with organic matter.

**Scarifiers and harrows:**

They are used for shallow cultivation to create mulch at surface of soil.

**Sweep plough:**

They are used for killing the weeds.