DEBRE MARKOS UNIVERSITY

DEPARTMENT OF PLANT SCIENCE

A TEACHING MATERIAL FOR THE COURSE

Field Crops Production

Chapter 1: Introduction

1.1. Definition & importance of field crops

Crop: A plant or a collection of plants produced artificially or naturally for the benefit/device of man.

Crop production - a systematic and planned production of cereals, pulses, oil crops, root and tuber crops, fiber crops, beverage crops, for profit or subsistence. It includes agronomy, soil science, entomology, pathology, microbiology, etc. The aim is to have better food production and how to control the diseases.

The use of the phrase '**field crops'** is used as opposed to the phrase 'horticultural crops'. The word horticulture is derived from two Greek words '*horti'* (meaning around home stand) and '*culture'* (meaning growing). Usually horticultural crops are cultivated around homes as compared to 'field crops' that are grown away from homes, i.e. in fields. **Field crops** are crops (other than fruits or vegetables) that are grown for agricultural purposes; cultivated plant that are grown commercially on a large scale. Field crops are sometimes called agronomic crops. The term field crops can be include: Cereal and legume crops are used as a source of food, feed (for livestock), fuel, medicine, alcohol. Oil crops are mainly grown for the production of oil from their seeds.

Importance of Field Crops

Humans cannot survive without crop plants.

Crop used:

a) **Food for human and feed for livestock:** Human and other animals require energy, amino acids vitamins, and minerals. The most important crops that feed the world include Cereals (wheat rice, maize, sorghum, barely), Roots and Tuber crops (potato), Oil crops (linseed, sesame, sunflower, Soya bean)**,** Fruit crops and Vegetable crops.
b) **Wood and wood products from fiber crops:** Construction, Furniture**,** Fuel and Paper.
c) **Textiles from fiber producing crops:** Plant fibers are used for clothing and textiles, examples Cotton, Sisal, flax
d) **Drugs and Medicines:** Examples Tobacco, Coffee
e) **Fossil fuels**

f) **Prevent erosion**
g) **Perfumes and spices:** Perfume-rose, Spice- pepper, ginger, for improving taste of food.
h) **Aesthetic purpose:** For great pleasure **,** relaxation
i) **Source of oxygen:** Oxygen is released as a byproduct of photosynthesis by green plants.

1.2. World population expansion & food supply

Currently human population reaches about 7 billion. In spite of worldwide declines in the total fertility rate, population growth will be continued for the next two or three decades. Approximately 99% of this growth will take place in the less developed areas of the world; Africa, Asia & Latin America. Now, the area of greatest food production is North America, the least populated of the developed areas of the world. While North America enjoys food surpluses, Sub-Saharan Africa, is experiencing a chronic food deficit. Periodically, famine strikes the Sub-Saharan Africa because of drought, often worsened by regional conflict.

The international community; non-governmental organizations & United Nations agencies, have so far had the capability & the resources to alleviate famine. But, the response has not always been timely, and then, the future is uncertain. Therefore, continued population growth requires continued increases in food production. During the last-century, worldwide food production from farming has kept rapidity with population growth. The green revolution involved the development of disease-resistant and drought-resistant strains of wheat and rice which have substantially increased the yield per unit of land. Development of a dwarf variety of wheat in the 1950,s was the beginning of the green revolution by **Norman Borlaug**. Mexico, which had been threatened with food shortages, became able, for a time, to produce a food surplus. India had experienced famine in the 1960,s but after the green revolution was introduced there, India also was able, for a while, to produce a surplus. The green revolution provided an additional twenty years pardon before population growth absorbed an increases in food production.

Status of field crops production in Ethiopia

The results of the year 2017/18 (2010 E.C.), Meher Season Post-harvest Crop Production Survey indicate that a total land area of about 12,677,882.27 hectares are covered by grain crops i.e.

cereals, pulses and oilseeds, from which a total volume of about 306,126,383.06 quintals of grains are obtained, from private peasant holdings.

Table 1. Total Area and Production of Grain Crops for Private farmer holdings, 2017/18 (2010 E.C.), Meher Season

Crop Category %	Total Area in Hectares	%	Total Production in Quintals %	%
Cereals............	10,232,582.23	80.71	267,789,764.02	87.48
Pulses.............	1,598,806.51	12.61	29,785,880.89	9.73
Oil Seeds ……	846,493.53	6.68	8,550,738.16	2.79
Grain Crops …	12,677,882.27	100.00	306,126,383.06	100.00

Within the category of Grain crops, Cereals are the major food crops both in terms of the area they are planted and volume of production obtained. They are produced in larger volume compared with other crops because they are the principal staple crops. Out of the total grain crop area, 80.71% (10,232,582.23 hectares) was under cereals. Teff, maize, sorghum and wheat took up 23.85% (about 3,023,283.50 hectares), 16.79% (about 2,128,948.91 hectares), 14.96% (1,896,389.29 hectares) and 13.38% (1,696,907.05 hectares) of the grain crop area, respectively. Pulses are also among the various crops produced in all the regions of the country after cereals. Pulses grown in 2017/18 (2010 E.C.) covered 12.61% (1,598,806.51 hectares) of the grain crop area and 9.73% (about 29,785,880.89 quintals) of the grain production. Oilseeds refer to crops which are also classified within grain crops category, nonetheless. Oilseeds are grown to flavour the food consumed at home and earn some cash for peasant holders in the country. Oil seeds added 6.68% (about 846,493.53 hectares) of the grain crop area and 2.79% (about 8,550,738.16 quintals) of the production to the national grain total.

1.2. Challenges and opportunity of crop production in Ethiopia

A. Challenges

- **Subsistence production system:** It could be identified at least with the following five characteristics:
  - ⇒ Small and often fragmented land (0.5 to 2.0 ha)
  - ⇒ Primitive tools and implements
  - ⇒ Production geared to personal needs rather than to market
  - ⇒ Lack of alternatives or seasonal employment opportunities and
  - ⇒ Almost total absence of reserves of either grain or cash

- **Disease and pests:** On the average, the pre and post -harvest losses due to diseases and pests is 30-40%.
- **Policy Factors:** It is one of the decisive elements that have a direct relationship with agricultural productivity. Some of the policy factors that greatly hamper agricultural productivity are:-
  - ✓ Weak agricultural research policy development.
  - ✓ Lack of capacity and educated man power to handle new technologies.
  - ✓ Absence of polices and instruments to intervene in the interest of national food security.
  - ✓ Weak and sporadic linkages between government agricultural policy institutions, agricultural research institutions with the subject people (farmers).
  - ✓ Lack of Education and skilled manpower in most rural Ethiopia.
  - ✓ No clear-cut policy was formulated to benefit the rural poor.
  - ✓ Farmers' indigenous knowledge, community resources and the ability of farmers to be experimenters in their own right are not taken in to consideration as huge potential to be unleashed. Besides, farmer to farmer linkage and role in technology adoption and dissemination as well as linkage of actors and different cross cutting issues are not built into the extension system and thus the potential is not exploited.
  - ✓ Another major challenge related to policy is the limited awareness and limited contribution towards policy formulation and implementation at the lower levels of the agricultural systems.
- **Lack of technologies:** We have not been able to design appropriate technologies (for land preparation, crop establishment, irrigation etc.) for a range of ecological settings to maximize production, minimize losses (pre and post-harvest) and increase value added (processing). Appropriate technologies with distinctive advantage over existing ones for harnessing the different agro-ecological areas are generally lacking. Most of the draft animals for agricultural operations are generally weak and the harnessing system is inefficient.
- **Social Infrastructure:** Social infrastructures such as hospitals, clinics, schools, water supply, etc. are lacking in rural areas. Rural people have to travel long distances in search of these facilities.

- **Food aid :**It should be borne in mind that, the majority of the farmers particularly farmers of north– central Ethiopia have assumed and some even accepted food–aid as the only, or in many cases the most efficient means of addressing food security since they are landless and are tied by the strong twin forces of religious and cultural practices.

  - Negative impact on producer's income thereby increasing the dependency on future food aid.
  - A major effect in further depressing Ethiopian grain prices especially in the years of high production (Mesfin, 1984).
  - Market uncertainty for domestic grain traders (Demeke and Freed, 2004).
- **Natural Climatic factors:** several natural climatic factors are responsible for low agricultural productivity in Ethiopia. Some of them are weather changes, soil erosion and lack of adequate rain fall (recurrent drought).

B. Opportunities

1. Plentiful **labor**
2. Varity of agro **ecological zone**

   With altitudes ranging from 125 meters below sea level to 4,620 meters above it, the country has 18 major and 49 sub agro-ecological zones, each with its own agricultural and biological potential. Thus the country possesses one of the largest and most diverse **genetic resources** in the world.
3. Ethiopia has the soils and **climate** required for the production of a variety of food crops.
4. Ethiopia has also more than 80 million hectares of arable **land** out of which 16% is under cultivation.
5. Surplus **water** for irrigation. Over all irrigation development potential is estimated at 3.7 million hectares of land while only 5-6% of this area is currently utilized. Irrigable large scale farms such as in the Rift Valley have big potential for the expansion of cash crops such as sugar, oil seeds and horticulture.

1.4. Means for increasing crop production and productivity in Ethiopia

Even thou most Ethiopian farmers follow traditional crop production system, they have mechanisms to grow better crop and to maximize productivity. The following are major activities to do this:

1. Maximizing arable land use

For continued productivity, arable land already in food production must be protected against high salinity, poor drainage, soil erosion, and contamination, which can limit yields. Some cropping procedures that can maximize arable land usage for food production are accomplished by the following:

1) Sequential cropping: growing two or more crops in sequence within the growth period

2) Intercropping: growing two or more crops simultaneously on the same land depending on crop interaction, either as mixed, row, or strip plantings

3) Ratoon cropping: regrowth of the same crop after harvest occurs from suckers or adventitious shoots.

2. Soil conservation practice

Conservation tillage leave at least 30% residue cover on the ground. This simple, low-cost practice can have a huge impact on the amount of soil eroded. Because of energy savings and obvious improvements in soil quality that can result from conservation tillage (especially from legume crop residue)

Contour farming and strip cropping is the practice of planting along the slope instead of up-and-down slopes, and planting strips of grass between row crops.

Cover crops are crops such as rye that grow in late fall and provide soil cover during winter. By providing a cover to the soil, winter soil erosion from both air and water can be greatly reduced.

Grassed waterways protect soil against the erosive forces of concentrated runoff from sloping lands. By collecting and concentrating overland flow, waterways absorb the destructive energy that would otherwise cause channel erosion and gully formation.

Terraces are structural practices that can reduce erosion by holding back the water and routing it along a channel at a lower velocity to where it can be safely discharged, usually into a grassed waterway.

Windbreaks are the best way to protect soil from wind erosion.

3. Prevention of production and post-harvest losses

Much of the crop production is lost because of unfavorable weather caused by temperature extremes, droughts, winds, or floods. These situations are difficult to avoid, although an expansion of irrigation use can avoid some drought conditions. Effective water utilization is often a key factor in avoiding production losses and wind breaks, flood control and temperature modification also can lessen losses. Other production losses are due to weed competition, disease, and insect infestations. Improvement in plant resistance and effective pest managements with pesticides and biological controls can limit some of these losses. Inappropriate harvest and postharvest handling practices further contribute to physical and quality losses of products. Postharvest crop perishability loss most commonly results from moisture loss, decay, and physical damage, respiratory loss, as well as other factors such as the development of off-flavors or discoloration. Deterioration losses also occur because of inadequate or poor storage and/or inability to accommodate surplus production or to process some of the production.

4. Good agronomic activity

- Increase tillage frequency and prepare good field with friable soil.
- Keep seeding time by considering onset of rainfall
- Provide cultivation and weeding,
- Application of different organic(animal dung & compost) and inorganic (DAP & Urea) fertilizers
- Effective pest control (cultural, physical or chemical)
- Keep time of harvesting and prevent loss at storage

5. Managing the population growth

When we are in a difficult condition to provide jobs so as to earn reliable income for food security, to produce sufficient food for the population, to provide basic needs (food, shelter, clothing) and social services like education, health, infrastructure, etc then the other equally important area that requires due attention is managing the population growth. For developing countries like ours the issue is to reduce fertility levels from the present global average 4 to about 2. In our country, the number of children per mother is nearly double the world average but the extent of poverty is one of the highest. Hence, we must be concerned as to how to manage the growth of the population to prevent disastrous outcomes. To this end, policy related to population and family education and mechanism to assure continuity of effects is critically necessary.

6. New food sources

The development of new food from other than most of conventional sources can increase the overall food supply. The oceans and seas offer huge resources of potential food. For example, algae & lower form of plant life. Development of new vegetable species from germplasm resources not currently utilized can make significant contributions. Biotechnological applications offer a huge potential for the development of new cultivars as well as the improvement of many presently cultivated crops.

Chapter 2: Classification of crop plants

It is well known that there are more than 600 cultivated plant species, From which there are about 100- 200 species play important role in the world trade. However, only fifteen plant species represent the most important economic crops. Therefore, these crop species must be classified or grouped in a convenient way to facilitate communication, dissemination and retrieval of scientific information as well as promotes the conservation, and improvement of certain plants. Generally, classification of these species is important for these reasons:

1. To get acquainted with crops.
2. To understand the requirement of soil & water different crops.
3. To know adaptability of crops.
4. To know the growing habit of crops.
5. To understand climatic requirement of different crops.
6. To know the economic produce of the crop plant & its use.
7. To know the growing season of the crop
8. Overall to know the actual condition required to the cultivation of plant. Field crops have been classified on the basis of botany, agronomy, duration of life cycle, special purpose, season and zone of origin in which they are grown etc as indicated below.

2.1. Botanical classification

Botanical classification is based up on similarity of plant parts. According to the botanical classification we can summarize the families of the most important field crops as follows:

1- Monocotyledons:

i). Gramineae/Poaceae family: The grass family includes about 3/4 of forages crops and all grain cereals crops. They possess long narrow leaves with parallel veins and fiber roots. They are annuals, biennials or perennials. The flowers are perfect and collected in inflorescence at the top of plant. The grain may be free (wheat) or enclosed (oats). The annual crops of this family are wheat, barley, maize, sorghum etc. while perennial crops is sugarcane, Napier grass etc.

ii). Liliaceae: includes onion, shallot and garlic.

2- Dicotyledons:

i). Leguminaceae/fabaceae family: It ranks next in importance to grass family. Plants possess broad leaves with alternate compound, stipulate, with netted veins. and tap root system which bears nodules. Legumes may be annual, biennial, or perennial. The flowers are buttery- like. The fruit in a pod contains one to several seeds. The seeds have two cotyledons being thick and full of stored food. The common annual legumes are horse bean, haricot bean, field peas, chickpea, cowpea, soybean etc. while perennial legume is alfalfa, Lucerne etc.

ii). Some Other botanical families in dicotyledons are as follows:

- Cucurbitaceae family includes pumpkin, cucumber
- Convolvulaceae family includes sweet potato
- Solanceae family includes potatoes, pepper, tomato, tobacco
- Asteraceae family sunflower, safflower, rape seed
- Malvaceae includes cotton.
- Linaceae includes flax.
- Pedaliaceae includes sesame.

Generally, the most important field crop family belongs to two botanical families, the grass family (**Gramineae**) and the legume family (**Leguminaceae**).

2.2 Agronomic classification

This type of classification of plants identifies a plant's agricultural use or economic importance.

⇒ **Cereal crops: -** These crops are grown for their edible grains rich in carbohydrate. They include Wheat, Barley, Tef, Maize, Sorghum, F. Millet.

⇒ **Pulses/grain legumes:** - These crops are grown for their edible grains rich in quality protein. They include Faba bean, Field pea, Cow pea, Soya beans, Lentils.

- ⇒ **Oil crops: -** These crops are grown for their edible oil. They include Sesame, Sunflower, Safflower, Rape seeds, Linseed.
- ⇒ **Sugar crops: -** Grown for their sugar content and includes: Sugar cane (60% sugar come from this crop in the world), Sugar beet (40% sugar from this crop).
- ⇒ **Fiber crops: -** They grow for their fiber and this includes Cotton, Sisal, Kenaf.
- ⇒ **Root & tuber crops: -** These are grown for their enlarged roots or tubers. Important root and tuber crops are Cassava, Sweet potato, Potato, Yam.
- ⇒ **Drug crops:** - These crops are smoked or chewed for their stimulant effect. They include Tobacco, Chat
- ⇒ **Beverage crops: -** These crops are also sources of stimulants. They include Coffee, Tea, Cocoa
- ⇒ **Vegetable crops: -** This group includes Tomatoes, Onions, Cabbages, Lettuce, Carrot, and Cucumber.
- ⇒ **Fruit crops: -** This group includes perennial fruit bearing crops. They include Papaya, Mango, Avocado, and Banana.
- ⇒ **Forage crops: -** Crops grown as feed for ruminants. They are fed to the animals either fresh or in dried form, such as hay and silaga (e.g. Alfalfa)

2.3. Special purpose classification

The name of the group is often derived from the purpose for which the crop is used. Many of the crops previously mentioned are well suited for more than one purpose. Some of the special purpose groups are as follows.

A. **Cover crops: -** These crops are sown so as to make a growth to cover or protect the soil. Example Alfalfa, Vetch, Cow pea, ...
B. **Green – manure crops: -** Those crops, which are grown to be plowed under or to be disked into the soil to increase its productivity. As a rule

  - ❖ Legumes are more desirable than non legumes
  - ❖ Fast growing crops are preferred to slow growing
  - ❖ High biomass producing crops are preferred to low biomass-producing crops. Example Cow pea, Vetch, Sesbania, ...

C. **Catch or emergency crops:** - crops used as substitutes for staple crops that have failed on account of unfavorable conditions. They are quick growing crops. E.g. millet and chickpea
D. **Soiling crops:** - Those crops are cut/harvested green and fed green to cattle directly from the field at their succulent stage. E.g. Alfalfa, Clover, Grasses, maize, ...
E. **Companion crops:** - It is an inter-cropping system. e.g. legumes and cereals
F. **Trap crops:** - Planted to attract pests.
G. **Alley crops**: crops are grown in alleys formed by trees or shrubs to increase soil productivity and reduce soil erosion.

2.4 Classification based on duration of life cycle

Crop plant completes their life cycle after passing through progressive stages of development during certain period of time (i.e. from seed, to seedling, to flowering, to fruiting, to death and back to seed) are grouped in to three categories as follows:

I) Annual crops: crops that complete their life cycle within a season or a year. Most of field crops are annual in nature; they produce seeds within a season or year and die. Example- rice, wheat, barley, maize, Faba bean etc,

II) Biennial crops: crop plants that complete their life cycle in two successive seasons or two consecutive live years. During the first year they produce leaves and stored food and in the second year they produce fruits and seeds after which plant dies. Examples: cabbage, carrot, sugar beet etc.

III) Perennial crops: the plants that live for three or more crops seasons are termed perennial crops. These plants may be seed bearing or no seed bearing. They may be propagated by seed or by vegetative propagation such as sugar cane, Napier grass, ginger and sweet potato or may produce fruits like citrus groups, mango, avocado etc.

2.5.Classification based on Climate Requirement

Crops are classified on the basis of temperature, altitude or latitude, since temperature, altitude and latitude have strong relationship, classification of crops based on temperature, altitude and latitude matches one to another

Classification crops based on climate requirements

Temperature Req.	**Altitude Req.**	**Latitude Req.**
1. Warm weather/ season crops	Lowland crops	Tropical crops
2. Cool weather/season crops	Highland crops	Temperate crops

1. Warm season/lowland/tropical crops are originated in the tropics and they include: maize, sorghum, millet, rice, haricot bean, soya bean, groundnut, cotton, sesame, sugarcane, pepper, sweet potato, tomato, etc

2. While cool season/highland/temperate crops are originated in the temperate regions and they include: barley, wheat, rye, field pea, faba bean, rape seed, flax, potato, cabbage, sugar beet, lettuce, spinach, garlic, etc.

2.6. Classification according to root depth

It is clear that the root system of field crops differ in structure, function and extent. Therefore, field crops can be classified according to the depth of their roots as follows:

1. **Hallow root crops**: the root system of these crops extends in the soil to a depth of one meter such as wheat, barley and rye.

2. **Intermediate crops**: the depth of the root system of these crops ranges from 1- 1.5 meter in the case of faba bean and sugar beet.

3. Deep root crops: the root system of these plants extends in the soil to a depth more than 1.5 meter as in alfalafa.

2.7. Classification according to Co_2 fixation

1. **C3 Plants**: Net assimilation rate in these plants is low (15- 40 mg Co2/ d2) but compensation point is high (30-70 ppm). Stomata are open during the day. Photo respiration is high in these plants C3 Plants have lower water use efficiency. The initial product of C assimilation is the three 'C' compounds. The enzyme involved in the primary carboxylation is ribulose-1,-Biophospate carboxylose. E.g. Rice, soybeans, wheat, barley cottons, potato. C3 plants include more than 95 percent of the plant species on earth. (Trees, for example, are C3 plants.)

2. **C4 plants**: Net assimilation rate in these plants is high (40- 80 mg Co2/ d2) but compensation point is low (0- 15 ppm). Stomata are open during the day. The primary product of C fixation is four carbon compounds which may be malice acid or acerbic acid. The enzymes responsible for carboxylation are phosphoenol Pyruvic acid carboxylose which has high affinity for CO2 and capable of assimilation CO2 event at lower concentration, photorespiration is negligible. These are said to be drought resistant & they are able to grow better even under moisture stress. C4 plants translate photosynthates rapidly. E.g. Sorghum, Maize, sesame etc.

3. **Cam plants**: (CAM stands for Crassulacean Acid Metabolism) the stomata open at night and large amount of CO2 is fixed as a malice acid which is stored in vacuoles. During day stomata are closed. There is no possibility of CO2 entry. CO2 which is stored as malice acid is broken

down & released as CO_2. In these plants there is negligible transpiration. C4 & cam plant have high water use efficiency. These are highly drought resistant. E.g. Pineapple, sisal & agave

2.8. Classification according to mode of pollination

1. Naturally self-pollinated crops: - the predominant mode of pollination in these plants is self-pollination in which both pollen and embryo sac are produced in the same floral structure or in different flowers but within the same plant. Examples: rice, most pulses, okra, tobacco, tomato.

2. Naturally cross-pollinated crops: pollen transfer in these plants is from the anther of one flower to the stigma of another flower in a separate plant, although self-pollination may reach 5 percent or more. Examples: corn and many grasses, avocado, grape, mango, many plants with unisexual or imperfect flowers.

3. Both self- and cross-pollinated crops: these plants are largely self-pollinated but varying amounts of cross-pollination occur. Examples: cotton and sorghum.

Chapter 3: Factors affecting field crops production

Plant growth is complex process and influenced by 4 major factors: 1. Environmental factors 2. Socio-economic factors 3. Crop factors and 4. Management factors (cultural practices) Environmental, socio-economic and management factors are external factors (extrinsic factors), while crop factors are internal factors (intrinsic factors). Simply it is also possible to conclude that crop production is governed by two factors: extrinsic and intrinsic factors, crop production = f (E, I) where: E= extrinsic factors, I= intrinsic factors

3.1. Crop /genetic /internal factor

Crops vary in their needs for water, nutrients, sunshine and day length, and agronomic management strategies. For example, water is very critical in the growth and production of sugar cane, bananas, plantains, rubber and to some extent, oil palm and pawpaw. Whereas in the production of cotton, groundnut and beans (legumes in general), sunshine and day-length are the most critical. Therefore, in the selection of what to grow, you must bear in mind the variables which encourage the crops to perform optimally. Unless, you are prepared to create a micro-climate or environment for the crops of your choice, you should as a matter of importance check through the list of crops that perform optimally in the (selected) environment where you intend to grow the crops. For example, swamp rice (paddy rice) requires pre-nursery and nursery operations in the production of the rice seedlings; upland rice does not require pre-nursery and nursery operations. Most tuber crops do not perform well in swamps or water logged areas. Similarly, most cereals require heavy sunshine, moderate water/rainfall and well drained soils.

Generally: a crop cultivar has an inherent yield potential. To make best use of climatic and soil factors the selection of crops should be made on their best qualities based on:

a. Adaptability under the particular set of condition
b. Yield potential (productivity)
c. Resistant to a biotic and biotic factors

3.2. Some socio-economic factors affecting crop production are:

- Consumption preference
- Living standard
- Income level/source of income
- Level of development
- Marketing mainly market access and price
- Labour availability
- Technical/economical feasibility and affordability, etc.

3.3. Environmental (External) factors

The environment in which crops are grown can influence the rate of growth and development. **Environment** is defined as the aggregate of all the external conditions and influences affecting the life and development of plants. Agronomic adjustments necessary for higher yield are aimed at creating optimal conditions for crop production to the extent possible. Major factors of plant environment can be broadly grouped into two: **climatic and edaphic (soil).**

3.3.1. Effect of Climate:

It refers to the total complex of weather conditions, its average value and range of variation over appreciable areas of the earth's surface, usually conditions for many years (30 to 35 years) are taken into consideration. Climate largely determines the type of vegetation that grows naturally in any part of the world and the kind of agricultural production that is possible. The most important climate factors are: Moisture (water) supply, Light, Temperature, Humidity, Wind and radiant Energy.

A. **Moisture (water):** Water is absolutely essential of plant life. Plants use more water than any other substances they absorb.

Importance of water in plants: - the essential requirement of water for plant growth can be visualized from the fact that it may constitute 70 to 95 of total fresh weight when it is actively growing. It is used for Universal solvent for chemical reaction, dissolves essential nutrients through the plant, cell turgidity and for cell elongation so maintain shape and photosynthesis etc. Plants can be classified according to the amount of water they require for normal growth:

1. Xerophytes – require little water. Example most desert plants
2. Mesophytes- require moderate amount of weather .Cereals, legumes
3. Hydrophytes- require large amount of water. Example , rice

Transpiration ratio: the amount of water transpired in relation to the amount of dry matter produced. For examples, the crops barely in order to produce 1 unit or dry matter plants require 800 units of water is transpired. The crop maize also in order to produce 1 units of dry matter plant require 370 units of water is transpired. Even within the same crop this ratio varies.

The actual amount of water required by the plant varies depending on the Plant population, fertilizer application, Stages of growth, Photosynthesis, Relative humidity and over all plant health.

Plant population: Within the limits of available moisture nutrients and other variables, as population density increases, yield increase and total water use also increase, at the same time it allows more efficient utilization of weather because the soil is permitted with roots so the maximum amount of moisture that enters the soil is extracted from it and transpired by the crops.

Fertilizer application: When adequate moister is available, yield increase with application of appropriate fertilizer (especially N) and the water required to produce dry matter may decrease. It helps to enhance more efficient utilization of water. Additional nitrogen application helps vigorous (more) root growth, exploitation of soil by root and to extra more water. When adequate moisture is not available, the benefit of fertilizer application is reduced by Excess application may damage crop because fertilizes can burn root tissue , and Excess nitrogen result in abundant vegetative growth, water required to support such growth which drains the soil available moisture before the crop is matured, thereby reducing crop yield.

Stage of development: The crop passes through various growth stages. Seedlings generally have less efficient water utilization than mature plants because root systems don't fully exploit large volume of soil, and seedlings do not shade the soil surface which results significant amount of water are lost from the soil by evaporation.

Photosynthesis: Water use is high when the photosynthesis rate is high.

Relative humidity: It is the amount of water vapor in the air at particular temperature compared with the amount of water vapor that the air could hold at the temperature. When there is low RH in the atmosphere, the concentration difference is high and then transpiration is high.

Health of the plant: The overall health of the plant greatly affects its water use and water use efficiency Plants that are infected by any of the pathogen have 3 greatly reduced water use efficiency, high transpiration and reduced yields.

Rain fall: Precipitation is the process by which condensed water vapor from the atmosphere falls to the earth's surface reaching in different forms inducing rain, snow and ice. Rainfall is the most important forms of precipitin in crop production. The minimum amount of rainfall on a single occasion that ensures at least some soil water storage is usually referred to as **effective rainfall**. The effectiveness of rainfall in crop production depends on three of its characteristics- quantity, distribution and duration. Light showers usually end up evaporated from the soil. Moderate RF over a longer period is more useful than a rain that delivers several inches of moisture in a short period. Much of such RF will be lost to surface drainage and not available to crops. It might even by accompanied by soil erosion that will be detrimental to crop productivity. The amount of water by itself is not a very high value unless it is distributed throughout the life of the crop. For example in maize production the critical time when moisture is needed is 10 days after tassel ling and silking. For most crops this time occurs around flowering. Therefore, RF is of most value to crop productivity when it falls at these critical periods in the plant growth and development.

Table 2. Agricultural crop production regions may be described on the basis of annual precipitation

Annual RF	**Crop region**	**Cultural strategy for success**
< 250 mm	Arid	Production is dependent on supplemental water supplied through irrigation
250-700 mm	Semi arid	Production methods that conserve water; moisture conserving practices; irrigation often needed
700-1000 mm	Semi –humid	Natural precipitation does not limit crop production
>1000 mm	Humid	Moisture not a problem but diseases is common problem

B. Light / Solar Radiation

This is the radiant energy from the sun, measured as a total amount (direct solar plus sky radiation). Radiant energy is significant factor in plant growth and development as the permeability of protoplasm, intake and loss of water, enzymatic activity, respiration, photosynthesis, flower initiation and ripening of fruits are all influenced by light directly or indirectly. Solar radiation is very important in crop production as is a source of energy used by plants for photosynthesis, the effect of solar radiation on crop productivity depends on the angle at which it strikes the earth, the cloud cover, and the interception by plants. Three aspects of light: **intensity** (quantity), and **duration** (day length), **quality** (spectral distribution) are important.

Table 1.1 Major plant physiological processes controlled by light (Fitter and Hay 1981)

Process	Effect of light
Germination	Effects on dark and light requiring seeds
Stem extension	Etiological effects
Leaf expansion	Prolonged illumination required for full pigments
Chlorophyll synthesis	Illumination required for development of green pigments
Flower production	Photoperiodism and the control of flowering
Bud Dormancy	Photoperipdic response induced in short days

Total amount of radiation reaching soil surface or crop is a function of the intensity and duration. The efficiency of light interception by a crop is dependent on many factors

- The ability of crop to produce full leaf cover early in the season like Maize, sugar cane,
- Plant population density. Crops grown in wide rows are less efficient in early parts of season than grown in narrow rows,
- Leaf arrangement. Rosette leaf arrangement (sugar beet) is less efficient than cereals leaf canopy,
- Leaf angle. Plants with more erect leaves are generally more efficient than those with leaf angle closer to the horizontal,

- Tillering. In cereals , tiller number, in general, increases with increasing irradiance,
- Type of growth. At very low levels or in dark, etiolation of shoots occurs leading to weak growth.

Light Quality: the wave length of the radiation determines its quality. Plant pigments associated with photosynthesis have different absorption spectra. They absorb different wave length of light. Leaf chlorophyll absorbs radiation efficiently at 400-500 nanometers (blue) and 650-750 nm (red), these radiant energy wave length ranges that are most important to photosynthesis is considered to be only useful part photosynthesis active radiation (PAR).within this range, it is known that different pigments involved in photosynthesis have different wavelength where light absorption is maximum. However, in practice, light quality cannot be manipulated under field conditions.

Light Intensity: light intensity measures its quantity or brightness. Light intensity may be as high as 10,000 foot candle. Foot candle is a light produced by a standard candle.100-200 FC is minimum requirements to support the growth of most plants. 10,000Fc is maximum intensity of light that plants can use in photosynthesis under average field condition.

- Based on light intensity crops can be grouped:
  1. Sun plants: - reach saturation at light intensities of 5000 or more FC. Examples, most crop plants
  2. Shade plants: reach saturation at about 500 FC.
     Example: coffee under forests.

Strategies for maximizing solar radiation interception and crop yield include:

- Early planting for earlier leaf area development ,
- Crop stand that will allow development of an optimum Leaf Area Index at maximum lead area development,
- Sowing at time that provide total ground cover during the period of maximum solar radiation levels,
- Uniform plant stand over the field to reduce early interplant competition and to increase solar radiation interception,
- Optimum fertilizer use to increase rate of growth and photosynthetic efficiency of leaf surface and,
- Extending the time of maximum radiation interception by active leaf surfaces

Light Duration: the duration of exposure to light periods (day-length and photoperiod) influence crop growth and development. The duration of light is measured by the hours of sunshine in 24 hours. The relative length of daily light and dark periods (photo-periodism) has a profound influence flowering, tuber formation and seed germination. Crop plants have been classified on the basis of their photoperiodic requirements for floral initiation into three groups.

I. **Long day plants (short night**):- are those which develop and produce flower normally when photoperiod is greater than a critical minimum (> 12 hrs. of light illumination).For example wheat, barely, sugar beet, oat.

II. **Short day plants (long night):-** are those which develop and produce flower normally when photoperiod is less than a critical maximum (< 12 hrs. of light illumination). For examples maize, rice, sugar cane, soya bean.

III. **Day neutral plants**: - the flowering development of such plants are not affected by photoperiod e.g. tomato, cucumber.

Most tropical crops are short day plants (requiring long –nights for flowering) and those of higher altitudes are generally long-day plants

C. Temperature

The measure of intensity of heat energy is called as 'Temperature". Growth and development are directly affected by temperature. Each crop has its own approximate temperature range, i.e. its minimum, optimum and maximum temperature limit at which growth is negligible or it ceases altogether and an optimum temperature falling between the two extremes. These maximum, minimum and optimum temperature ranges are known as Cardinal temperature. The cardinal temperature ranges for cool season crops are maximum 30-38 ^{0}C, minimum 0-5 ^{0}C and optimum 25-30 ^{0}C and also for warm season crops maximum 45-50 ^{0}, minimum 15-20 ^{0}C and optimum 30-38 ^{0}C.

Optimal temperatures for crop growth are dynamic as they differ with crops and varieties, duration of exposure, age of the crop and developmental stages. Most crops make their best development between 15 and 32^{o}C. All the biochemical processes increase with increasing temperature up to a certain level beyond which and below a minimum temperature these activities are reduced. Temperature directly influences photosynthesis, respiration, cell wall permeability, nutrient and water absorption, transpiration, enzyme activity and protein coagulation. This influence reflects on crop growth. The effect of temperature on net photosynthesis is of vital concern in crop production. Plant growth is greatly affected by high temperature in several ways- inhabits starch synthesis, affect shoot growth, pollen malfunction resulting to reduced yield, causes desiccation and change in enzymatic structures and function, on the other hand low temperature affects crop growth, Pollen sterility, flower and pollen blasting (premature dropping of flow end fruit), and burning of leaves. Based on their temperature response (adaptation) crops may be classified as:-

a) **Cool season crop** – damaged by hot weather. For examples wheat barely , potato, oat
b) **Warm season crop**- killed by temperature below freezing. For examples sorghum, cotton, rice, maize.

The relationship between temperature and crop management shows that the crop producers can do little or alter temperature, however, it is possible by adjust planting date(frost free period) and cultivar selection like early mature cultivars for areas with short growing seasons.

D. Humidity: - is the water vapor in the air. Relative humidity is the vapor pressure in the air in terms of the percentage necessary to saturate the atmosphere at a particular temperature. A saturated atmosphere that causes fog, dew, or rain has a theoretical relative humidity of 100%. The effect of humidity on crops is that the occurrence of high humidity over long periods combined with high temperature favors the rapid development and spread of fungal disease on crops and mold on stored produce. The lower the RH at a given temperature the more rapidly will the airs taken up water transpired by plant leaves or evaporated from a moist soil surface. Evapotranspiration increases with increase in temperature and decrease in R.H thus relative humidity has considerable effect on water requirement of crops.

E. Wind: - is movement of air in a horizontal direction. It originates either over the oceans or deserts. The effect of wind on plant growth and development are both physiologically and mechanically.

a) **Mechanical damages**: - The heavier sand particles carried by the wind causes soil erosion by scouring the soil surface. The strong wind in association with rain can cause lodging, stock breakage and grain shedding of grains.

b) **Physiological damages**: - induces evapotranspiration that affecting the water balance. Hot dry winds may also affect photosynthesis and hence productivity, by stomata closure and reduced rate of gaseous exchange. Provision of windbreaks in exposed areas can minimize the adverse effects of high wind speed (Reddy, 1999).

3.3.2. Edaphic/soil factor

Soil is a living body consists of weathered rocks, organic matter, water and living organisms. It is a natural medium for plant growth. Soil provides physical anchorage to plants and act as store house for water and nutrients needed. Following are the soil requirements for crop production

- Suitability for using cultural implements in crop production
- Resistance to erosion and management involved in profitable crop production
- Adequate soil moisture storage to meet normal crop requirements under natural rainfall or irrigation,
- Optimum aeration in the root zone depth for efficient root system development,
- Availability of nutrients, sufficient for normal yields, and
- Freedom from adverse chemical soil conditions Such as concentration of harmful soluble constituent.

Principal factors characterizing soil climate are soil air, soil temperature and soil moisture. Some of the soil factors that affecting plant growth:-

a. Soil Reaction /PH/:-It defines the soil acidity or alkalinity based on the hydrogen ion concentration of the soil and is measured in PH units. On the Ph scale, a value of 7.0 indicates a neutral reaction, all value below 7.0 indicate acidity while all values above 7.0 indicate alkalinity.

Each nutrient element has a pH range within which it is available to plants. Similarly, plants have pH adaptation, some being sensitive to acidity while others are sensitive to alkalinity.

- The optimum pH rang for most plants is …………………………6.5-7.0
- Most agricultural soils have a pH of between …………………….5.0-8.5
- Most plant nutrients are available with pH values ……………… 5.5-7.5

Therefore, the pH of the soil has significant influence on the availability of plant nutrients.

It also influences plant growth by affecting the activity of beneficial microorganisms. Most N-fixing bacteria are not very active in strong acid soils. Bacteria that decompose soil organic matter and thus release nitrogen and other nutrients for plant use also hindered by strong acidity.

b. Soil texture: - defined as the relative proportion of sand, silt and clay in the soil. The soil particles on diameter basis: sand ranges 2.00-0.05 mm, silt 0.05-0.002 mm and clay below 0.002

mm. An agricultural soils typically consists of a combination of all the three particles is called a loam.

Soil texture is very important in crop production. Fine textured sols (clay soils) generally have poor drainage and are prone to waterlogging. Poor- drained soils have low microbial activity but clay soils have high water- holding capacity, high cation exchange capacity (CEC), and the ability of soil to attract and hold cation. Thus, clay soils have high nutritional status while sandy soils, which are coarse-textured, have low CEC.

Clay soils are further described as heavy soils because it becomes very hard when dry, and sticky and poorly aerated when wet and so difficult to till. They impede root development and thus are not suitable or root crop production. Clay soils have a small micropore that impedes drainage. Sandy soils have more macro pores (large pores).Sandy soils are light soils and are easier to till, They also drain better, and are warm, However, crop production on sandy soils requires frequent irrigation to make up for its poor water -holding capacity. Soil texture is an important soil characteristic because it affects infiltration, retention of water, soil aeration, and adsorption of nutrients, microbial activities, tillage, the method and frequency of irrigation.

c. Soil structure: - It is the manner in which individual particles are arranged to form soil aggregate. Soil aggregates is a clump of many primary soil particles. Soil structures can be destroyed through soil compaction using heavy machinery, farm animals, vehicles, and raindrops. Poor soil aggregation is partly the cause of poor drainage and poor water holding capacity. Soil structure can be improved through, for example the addition of organic matter.

d. Soil fertility: - soil fertility is the ability of the soil to produce high yields consistently, provides environmental factors.

e. Soil constituents: - Even though the proportion will vary from one soil to another, a typical mineral soil consists of by volume Air (25%), Water (25%), Mineral (45%) and Organic matter (5%)

f. Soil depth: - insufficient soil depth for adequate root development is the most obvious physical property that can crop yield. There is a positive linear relationship between the effective rooting depth and yield of a crop.

g. Soil moisture: Essentially all of the water used by plants is supplied by the soil. Soil is made up of solid particles and pore spaces which the ideally pore spaces should occupy about 50 % of the soil volume.

Depending on the amount of water and its availability to plants soil moisture is declassified as

1. **Saturated soil**: the amount of soil moisture content at which plants can no longer obtain enough moisture to meet transpiration requirement. They wilt unless water is adds to the soil.
2. **Field capacity:** the amount of water remaining in the soil after being saturated and then freely drained.
3. **Permanent wilting point:** the amount of water in the soil at which plants will wilt and not recover when placed in humid atmosphere.

3.4. Management factors

Management factor concerns about different agronomic activities healed on field. Field crop production and productivity can be affected by:

a). site selection

b). land preparation – land clearing, primary tillage, secondary tillage, inter-tillage

c). soil and water conservation

d). drainage system/scheme

e). cropping system – Rain fed vs. irrigation; mono cropping vs. crop rotation; sole cropping vs. mixed cropping.

f). soil fertilization g. seeding

Chapter 4: Cropping system

Cropping system defined as the scheduling and cultivation of the various crops within the farm enterprise in a given agricultural year. It is the crop production activity of a farm. **Cropping system** deals with management of natural and other farm resources for cropping activity with maximum efficiencies which are realized for sustainable and higher yields per unit area per unit time without degrading the natural resource base. Thus, cropping systems approach, in contrast to component approach, encompasses wide range issues related to economic aspects of crop production, available resources and microenvironment at farm level in holistic manner**.** Cropping systems approach enables to address issues pertaining to:

- Maximizing system productivity on annual basis
- Utilization of resources with higher efficiency by considering various interactions and direct residual and cumulative effect in soil-plant-environment system
- Intensive input use vis-à-vis quality of environment and
- Sustainability of farm resources and environment in long term perspective

Depending on the resources and technology available, different types of cropping systems are developed on farms.

4.1. Shifting cultivation

Shifting cultivation: It was developed early in settled agriculture and persists with modification in many parts of the tropics. Originally, farmers cultivated a plot of land large enough to supply their family's need until soil fertility declined with continuous cropping. The farmers then moved on to another plot leaving the first plot to return to bush through regeneration of natural vegetation. The soil would recover its fertility during this fallow period. With increasing population and consequent reduction in availability of land, shifting cultivation has been replaced by sedentary occupation and reduced length of the fallow period. In most parts of the tropics, there are modified forms of shifting cultivation often involving land rotation.

4.2. Mono-cropping & Multiple cropping system

Monocropping/monoculture: It refers the growing of only one crop on a piece of land year after year. It may be due to climatological and socio-economic conditions or due to specialization of farmer in growing a particular crop. For instance under rain fed conditions, groundnut or cotton or sorghum may grown year after year due to limitation of rainfall. Tobacco may be grown in an area year after year due to specialization of the farmers/entrepreneur in growing it. Under waterlogged condition, rice crop may be grown, as it is not possible to grow any other crop. This is not a common system of growing crops in tropics except in plantations and swamp rice, sugar cane or large-scale maize production.

Multiple cropping: Growing two or more crops on the same piece of land in one calendar year is known as multiple cropping. It is the intensification of cropping in time and space dimensions, i.e. more number of crops within a year and more number of crops on the same piece of land at any given period. It includes **intercropping, mixed cropping and sequence cropping.**

Sequence cropping: Growing two or more crops in sequence on the same field per year. The succeeding crop is planted after the preceding crop has been harvested. Crop intensification is only in the time dimension. There is no space competition. Farmers manage only one crop at a time in the same field, such as:

Double cropping: Growing two crops a year in sequence

Triple cropping: Growing three crops a year in sequence

Quadruple cropping: Growing four crops a year in sequence

Ratoon cropping: Cultivation of crop regrowth after harvest, although not necessarily for grain e.g. Sorghum ratoon can be grown for forage. The first harvested is usually called plant crop and each succeeding harvest is designated as first ratoon, second ratoon etc. the term has been applied traditionally to sugarcane, pineapple and banana and more recently to grain and forage sorghum, cotton, rice etc. basically ratoon cropping implies:

- More than one harvest from a single planting
- Regrowth from basal buds on the stem or crown
- Harvesting of most or all the aerial portion of the plant

Advantages

- Reduced cost of production through saving in land preparation and seed materials
- Reduced crop cycle period for ratoon crop
- Better utilization of growing season in monsoonal climates
- Can be used in breeding to maintain the same plant of clone through several seasons and
- Less input (irrigation, water, fertilizers) requirement than main crop

Disadvantages

- Lower yield than plant crop
- Buildup of injurious insect, weed or disease problem

Inter cropping: - Farmers grow several crops simultaneously in the same season either by mixing their seeds or by growing them in separate rows. Both the crops may be sown or harvested at the same time or at different time. The intercrops are fast gowning and have short duration grown between two rows of slow gowning main crops. Crop intensification is in both the time and space dimensions. There is intercrop competition during all or part of crop growth.

There are basic spatial arrangements which are used in intercropping.

i) **Row intercropping** - growing two or more crops at the same time with at least one crop planted in rows.

ii) **Strip intercropping** - growing two or more crops together in strips wide enough to permit separate crop production using machines but close enough for the crops to interact.

iii) **Relay intercropping** - planting a second crop into a standing crop at a time when the standing crop is at its reproductive stage but before harvesting. For example, sowing of cucurbits in maturing potato crop.

Table 5.Difference between inter cropping and mixed cropping

Inter cropping	Mixed Cropping
Objective is to utilize the space left between main crops	Objective is to get at least one crop under any hazard
More emphasis is given to the main crops and subsidizing crops are not grown at the cost of min cops	All crops are given equal emphasis ; there is no min or subsidiary crop
No competition between crops	In all combination there is competition
One crop is long duration and the other is short duration	Almost the same duration
Crops are sown without affecting the population of main crop when sown as sole crop	sown without considering the population of either
Sowing time may be same or different	It is same for all crops

- **Evaluation of inter-cropping systems:**

Land Equivalent Ratio (LER): it is the relative area of a sole crop or sole crops required to produce the yield or yields achieved in inter-copping.

$$LER = Ia/Sa + Ib/Sb + Ic/Sc + . . . + InSn$$

Where Ia, Ib, Ic, …. In are the individual crop yields in inter-cropping, and Sa, Sb, Sc, . . . Sn are their yields as sole crops.

- A LER greater than 1 implies that for that particular crop combination, inter-cropping yielded more than growing the same number of stands of each crop as sole crop.
- A LER less than 1 implies that for that particular crop combination, inter-cropping was less beneficial than sole cropping.

- ❖ A LER equal to 1 implies that for that particular crop combination, yields harvested from inter-crops could have been obtained from the unit area planted to sole crop, and also the overall yield per unit area of inter-crop is not greater than that of the most productive sole crop.

Alley cropping: It entails growing food crops between hedge row of planted shrubs and trees, preferably legumes, the hedges are pruned periodically during the crops growth to provide the biomass and prevent the shading to the crops, Hence alley cropping can be conveniently considered as a form of hedge row intercropping.

Figure A. Distance between trees & crop

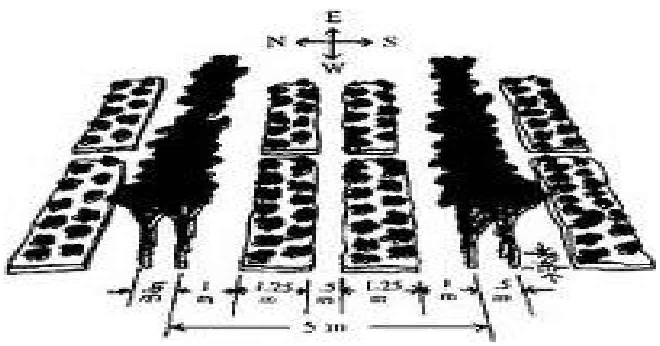

Figure B. Six rows of a crop between trees

4.3. Crop rotation: It is the sequence of certain number of crops in definite order on the same pieces of land over affixed period of time.

Factors to consider in deciding the sequence of crops (principles of crop rotation)

1. The target crop should be planted immediately after the legumes or fallow period. At this time the fertility of the soil is at its peak and the optimum realizable yield of the target crop is possible.
2. Crops which are deep feeders should alternate with shallow feeders. In this way, nutrient removal occurs uniformly from the various soil layers rather than occurring in only one layer.
3. Crops that are botanically similar or are likely to be attacked by the same diseases and pests should not normally follow each other in the rotation. Yams, for example, should not follow cowpeas in rotation if the root-knot nematode is prevalent, as the nematodes left over from the cowpea crop will severely reduce yam yields. However, if the nematode problem does not exist in the area, yam could conveniently follow cowpeas.
4. The number of years for each cycle of the rotation should run is determined by the number of crops in the rotation, the length of their growing seasons and how frequent the farmer can grow the target crop without running into problems of disease and soil fertility. For example, the time

interval between the harvesting of the target crop and its being planted again on the same piece of land should be long enough to prevent the carry-over of pathogens in crop residues from one cycle to the next.

Advantages of Crop Rotation

1. It is an effective means of controlling diseases and pests. The pathogens and pests of a particular crop are more likely to die off when their host crop is followed by a completely different non-host crop. Many insects are destructive to only one kind of crop. The life cycle is broken when crops grown are unfavorable to the development of the insect pest. Cotton root-knot can be reduced by the growth of immune crops in the rotation.
2. Crop rotation is the most effective practical method for controlling many farm weeds. Some weeds are particularly adapted to cultivated crops, the absence of such host crop in the field for many years due to rotation, effectively control the weeds. Rotation may include smother crop as a means of controlling certain weeds.
3. The type of crop rotation where the field is divided into several plots, offers the farmer some insurance against crop failure, and enables him to spread out his labour needs.
4. Crop rotation is an effective means of reducing erosion in comparison with continuous cropping. Grass legumes in a rotation have been very effective in the reduction of erosion.
5. A good rotation that provides for maintenance or improvement of soil fertility usually includes a legume crop to promote fixation of nitrogen.
    - For balancing nutrient removal from the soil E.g crops like maize yam and cassava are exhaustion, Vegetables such as tomato, ground nut are relatively less demanding
    - The different plant species is able to extract nutrients at different soil depth
        - Difference in the development of the root system
        - Rotate deep rooted crops with those having shallow root system.

4.5. Fallow cropping: Leaving the land free of crops for some times and cultivating for the other time.

Chapter 5: Agronomic practices/Crop husbandry/

5.1. Tillage/land preparation

Tillage: - it is the manual or mechanized manipulation of the soil to provide a medium for proper crop establishment and growth. There are **several purposes of tillage**, the major ones are:-

1. **Land leveling.** Land is leveled for several purposes.
2. **Seed bed preparation.** For proper germination to occur, the seed must make good contact with the soil to be able imbibe moisture.
3. **Incorporating organic matter and soil amendments.** Stubble left after crop harvesting can be mixed to improve its physical characteristics. Fertilizer, organic and inorganic, and soil amendments such as lime, may be added to the soil during preparation prior to seeding.
4. **Weed control.** Weeds compete with crop plants for growth factors and may harbor diseases and insect pests. Weeds are controlled at various stages in crop production.
5. **Improve soil physical conditions.** Tillage can be used to break up the hard pan for root growth and development
6. **Erosion control.** Tillage Provide a rough soil surface to impede the actions of the agents of soil erosion (conservation tillage).
7. **Shaping the soil.** To create raised beds for planting or to create furrows for irrigation.

There are **two basic groups of tillage** according to the degree of soil stirring.

1. **Conventional tillage**. The tillage system that leaves less than 15% of the soil covered with plant residue by clearing or remove plant remain materials on the soil surface. There are two types of tillage operation :
   a. Primary tillage. The mechanical manipulation of the soil that produces a rough finish unsuitable for seeding; usually precedes secondary tillage.
   b. Secondary tillage. The mechanical manipulation of the soil that produces a finer tilth for preparing a seedbed; usually follows primary tillage.

The conventional tillage has **advantages** include the following:

- ❖ Even though tillage may cause compaction, it is the most convent method of managing soil compaction when it occurs.
- ❖ It is easier to apply fertilizers and perform the agronomic operations when the land is clean.
- ❖ The lack of crop residue on the soil surface reduces the opportunity for overwintering / over summering of pests.

The conventional tillage has **disadvantages** include the following:

- ❖ Creates soil erosion

- ❖ Soil compaction. Creating a plow pan due to excessive and repeated use of primary tillage implements at the same depth places pressure on the soil.
- ❖ It is expensive
- ❖ Soil organic matter loss. Soil organic matter decreases over time.

2. **Conservation tillage**: entails practices in which some crop residue remains on the soil surface after the operation. The chief goals of this tillage practices are to reduce soil erosion and conserve moisture. There are different types of conservation tillage practices that vary in the degree of soil disturbance and the amount of crop residue on the soil surface like no tillage, mulch, strip, minimum tillage and ridge tillage. **Minimum tillage** can be defined as a method aimed at reducing tillage to the minimum necessary for ensuring a good seedbed, rapid germination, satisfactory crop stand and favorable growing conditions(Arnon 1972

Conservation tillage has **advantages t**hat include the following.

1. Reduces soil erosion from wind and water.
2. Reduces soil compaction.
3. Soil infiltration and moisture conservation is high because of a large amount of crop residue.
4. Reduce cost of tillage.
5. Soil temperature moderation.
6. Increase soil organic matter over prolonged periods of no tillage.

The **disadvantages** of minimum tillage include the following:

1. Dependence on chemicals. Drastically reduced soil stirring means chemical are depended upon in no-till operations for weed control.
2. Higher risk of insect pests and pathogens in early crop establishment because of soil-borne pathogen sand soil surface insects.
3. The higher soil moisture increases the chance of leaching of water –soluble bases and then tends towards acidity over time.
4. Crop residue impedes the application of fertilizer.
5. High levels of herbicide use increase the opportunities for the development of herbicide resistance. And also new weed problem may emerge under conservation tillage.

5.2. Planting material (seed) and seed quality

Seed is the living link between parents and its progeny. Biologically, seed is a ripe, fertilized ovule and a unit of reproduction of flowering plants. Agronomically, seed, seed material or propagule is the living organ of crop in rudimentary form used for propagation. It may be described as a plant embryo in dominant state surrounded by food supply and seed coat. A good crop stand and establishment depends on the quality of seed planted and the condition under which the seed was planted. It can be any part of the crop from which a new crop will grow.

Characteristics of Quality seed

Seed quality: - it is the ability of seed to germinate and emerge as vigorously seedling plants. Quality seed ensures uniform crop stand establishment with uniform vigour and population of seedling per unit area. Selection of good seed is, therefore, of prime importance for remunerative farming. The seed should be of adaptable crop variety or hybrid fitting into the cropping system

- Seeds have good yielding ability
- Seed should be pure (true to type) with high germination percentage,
- It should be free from seed borne diseases , insects and insect eggs,
- Seeds should be resistant to crop disease and pests.
- They should be materially well-developed, large, plump, bold, uniform in size, shape, colour with proper test weight,
- seed should be free from noxious, objectionable or satellite weed seeds, and
- The seed should be as fresh as possible or of proper age

Seed quality Index indicates the vigor of seed germination.

When a living seed fails to germinate even when provided with the normal condition necessary for germination (i.e. water, oxygen and temperature) such a seed is said to be **dormant.**

Method of planting

Seeds are sown either directly in the main field or in nursery bed, where seedlings are raised and transplanted in the main field appropriate age of the seedlings. **Direct seeding;** the crops are grown by sowing the seed directly in the main field. Direct seeding may be by broadcasting and row planting/ drilling.

Broadcasting: - random seed distribution is called broadcasting; Small sized seeds are difficult to plant individually. Most field corps seeded in this way. For examples wheat, oat teff, rice etc.

Advantages of broadcasting seeding include the following.

a. Rapid seeding

b. Suitable for small seeded crops that are difficult to plant separately.

Disadvantages

a. Uneven seed establishment

b. Require high seeding rate to make up for potential losses

c. Seeds may not germinate (not covered)

Row planting: - it entails more accurate spacing between seeds in a row and between rows. It is a patterned (structured) distribution

Advantages

a. Facilitate management practices/ cultivation, fertilization, pesticide application, harvesting)

b. Uniform of stand

c. To economize or optimize seeds and land resources.

Disadvantages

a. It is labor and time consuming

Seed rate

Seed rate plays a vital role in ensuring the presence of required number of plants per unit area. The seeding rate should be estimated as closely as possible for optimal crop stand establishment. Over seeding causes intense competition among plants whereas under seeding results in under utilization of resources and reduce crop productivity. The seed rate of a crop **depends up on** spacing, seed size, seed weight, germination percentage and purity percentage. Therefore, the seed needed to plant an area is estimated as a weight not account.

$$\text{Seed rate (kg/ha)} = \frac{Area(\text{m2})^{x}testweigh\ (g)^{x}100^{x}100}{1000^{x}1000^{x}germination(\%)purity(\%)^{x}spacing(m2)}$$

Seed rate of a particular crop is **influenced** by soil productivity, climate (high seed rate in wet climate), crop use (maize for silage has high seed rate) and germination ability of the seed.

Time of planting

Different crops are grown at different seasons depending up on their climatic requirement. Planting crops at proper time increases growth, development and yield of crops due to suitable environment available to the crop at its growth stages. Planting time is influenced by: Rain fall (moisture), Temperature in tropical and temperate regions, Occurrence of disease and pests, Marketing, Cropping system and Available of labor. Early planting may jeopardize crop establishment if unexpected adverse weather (e.g. frost) occurs. Late planting, similarly, may produce low yields because of the loss of part of the growing seasons.

Depth of seeding

Depth of sowing is another factor affecting proper seed germination and good plant stand. Uneven and improper depth of seeding results in uneven plant stands on growth, development and yield of crops. It is, there froe essential to sow the seeds of different crops at proper depth. The optimum depths of sowing of different crops depend up on:-

a. **Seed size**. Crops having bigger size sown at deeper depth while smaller seeds sown at shallower depth.
b. **Soil moisture content**. In relatively dry weather seeds sown deeply to contact with moist soil.
c. **Soil type.** Seed placement in heavy (clay) soils should be shallow and deep in light (sandy) soils. The optimum depth of sowing of most of the common cultivated crops generally ranges 3-5 cm.

5.3. Fertilizer use and its Management

Fertilizes are industrially manufactured chemicals containing higher amount of plant nutrient which are released quickly when applied in soil. Fertilizers are materials either natural or industrially manufactured, containing nutrients essential for the normal growth and development of plants. Manures are organic in nature and applied in large quantity and low nutrient content which releases nutrient slowly. They are animal or plant origin and contain more than one nutrient element. Fertilizers are organic or synthetic and nutrient content is higher than in manures. It supplies a particular nutrient or combination of nutrients.

Importance of Fertilizer Application:-soil is the cheapest and only ample source of nutrients which is not able to supply enough nutrients for crop production, if plant nutrients sources are not added from outside from time to time. Addition of fertilizer material from outside helps in maintaining the soil fertility and in turn better crop production is obtained.

Essential Plant nutrient: According to Arnon and Stout (1939)**,** for proper plant growth a regular supply of plant nutrients especially the essentials ones is necessary. Only 16 elements have been found to be essential for all the plants. These elements are N, P, K (Major/primary elements) Ca, Mg and S (secondary elements) Fe, Cu, Zn, Mn, Mo, Cl, B, C H_2, and O_2 (Micro nutrients) based the amount of nutrient is required by plant. Arnon (1954) has laid down the criteria to distinguish the essential elements. They are called criteria of essentially. These criteria are:

1. Plant must be unable to grow normally or complete its life cycle in the absence of the element.
2. The element is specific and cannot be replaced by another element.
3. The element plays a direct role in metabolism.

Type of fertilizes

Sources of Plant nutrient can be supplied to the soil by adding the following fertilizing materials,

I. **Organic Fertilizers**
   - ❖ Bulky organic manures e.g. farmyard manure, compost sludge, green manure
   - ❖ Concentrated organic manure e.g. oil cakes, poultry dung, urine, bone meal etc.
   - ❖ Bio-fertilizer e.g. Rhizobium, Blue green algae.

II. **Inorganic commercial Fertilizers e.g**. Urea-$(NH_2)_2CO$, DAP-$(NH_4)_2HPO_4$, Orga, TSP, SSP, etc.

Fertilizer Rate

Factors affecting level of fertilizer application depends upon:

1. **Crop types**:-Different kinds of crops require different amount of nutrients. The leguminous crops require less N than cereals. Improved cultivars, particularly when they are high yielding, normally respond more to increased fertilizer rate relative to unimproved local cultivars.
2. **Soil fertility**: The ability of the soils to supply the necessary plant nutrients differs greatly from one place to another and at different times. More fertile soils require less nutrients to produce a good crop and frequent cultivation makes the soil to decline the fertility through times. Large application of fertilizes can be profitable on soils that have a high productive potential but which are low in fertility. Therefore, an increase in the amount of nutrient applied to the soil may or may not increase crop yield.
3. **Growth stage**:-At earlier and midst age nutrient requirement is more than the later stages of crop growth.
4. **Moisture status:** If soil moisture status is good then response of fertilizer application is more fertilizer can be applied as compared to rain fed or dry land condition.
5. **Plant density:-**If plant density is more then apply less fertilizer at early stage and more in later stage and vice versa in less plant density.

6. **Cropping system Adopted: -** the combination of crop in the intercropping or in rotation also decides fertilizer level.

Methods of Fertilizer Application

Different fertilizers are applied either in the soil or on plants.

- **Broadcast**- it is uniformly spread on the surface. It may or may not be incorporated into soil. The lowest fertilizer efficiency obtained.
- **Banding**- for row cultivated crops fertilizer is placed in along with row crop It is preferable used large space between rows.
- **Split application** –fertilizer is added in two or more portions at different times during the season. Nitrogen fertilizer efficiency increased meanwhile P and K lower efficiency.
- **Side dressing**- strip placement and top dressing- fertilizer added after crop is growing. Side dressing can involve insertion of the fertilizer into soil besides the growing crop. Strip placement and top dressing may be placed as 'strip' on the soil surface near plants rather than being broadcast over the entire soil surface. They are put on after the crop is growing another split application.
- **Point injectors** – a narrow cylindrical tube (injector) penetrate the soil and allow liquid fertilizers to be inserted at depth yet avoid greatest root damages. For application of P and K fertilizers down into soil when roots grow. A pointed stick or lode is used to poke a hole in soil and fertilizer is poured into hole. It is used for fruit tree, vines, shrub and tomato.
- **Fertigation** – it is application of liquid fertilizers injected with water (as in irrigation water). For N fertilizer application with sprinkler and drip irrigation for green house plants.
- **Foliar spray**- application of liquid fertilizer to the foliage of plants, just enough to wet leaves. Foliage is wetted to allow maximum absorption through leaves. Mostly used for micronutrients for these required 1-10 kg/ha nutrients. Especially for Fe to protect immobilization in soil. Important when root of plants damaged low root uptake. Most spray required wetting agents (sticking agents). Spray left results salt burn if it is so concentrated so concentration should be 1-2%.

Time of fertilizer application

The time of fertilizes application depends mainly soil properties, crop nutrient uptake pattern and nature of fertilizer material. N, P, and K are taken up by plants in large quantities in early sates of their growth. N is necessarily for the synthesis of protein which are essential for the development of plant tissue.

After flowering, most of the crops especially cereals, contain lesser percentage of N due to greater accumulation of carbohydrates. It has been established that there is inverse relationship between nitrogen and carbohydrate in plants. The time of N application, therefore, depends on the end product of the crop. Fore examples, legumes require N until root nodules are formed which fix nitrogen. Nitrogenous fertilizers are soluble and highly mobile in the soil .They are, therefore, easily lost by leaching and volatilization. Phosphate and potassic fertilizers are loess mobile in soils as they are fixed/ absorbed on clay complex.

Optimal fertilizer efficiency

To ensure that a high proportion of fertilizer is used by crop plants, it is important to absorb the following points.

1. Avoid single large fertilizer application particularly N or in sandy soils where rainfall could cause leaching so that in such condition split application of N is advocated
2. Avoid top dressing of urea fertilizer to reduce losses through volatilization of ammonia, if broadcast or band placement, the urea should be covered with soil.
3. When fertilizer application is at planting, care should be taken to avoid direct contact with seeds.
4. It is best to broadcast phosphate fertilizers and incorporate it in to the soil before planting.

Integrated Plant Nutrient Management / IPNM/

IPNM is the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired levels of crop productivity through optimization of the benefits from all possible sources of plant nutrients in an integrated manner. Integrated use of chemical and organic fertilizer is required to supply and maintain soil fertility for sustainable crop production. Therefore, balanced fertilizer use must be based on the concept of integrated management for a cropping system. The **basic objective** of integrated nutrient use is

- To reduce the use of inorganic fertilizer in order to restore organic matter in the soil,
- To enhance nutrient use efficiency ,
- To maintain soil quality in terms of physical chemical and biological properties and
- To improve soil productivity and also provide higher yields.

5.4 .Crop protections

Agricultural pests are one of the most limiting factors of crop production in Ethiopia. A **pest** is any organism which harms man or his property or is likely to do so. It estimated that insect pests, disease and weed reduce half of the food produced in the world at the time of growing, transporting and storing of crops. Insect pest and diseases account about 35% yield reduction.

5.4.1. Weeds

Weeds are defined as any plants growing where man does not want them. Weeds encompass all types of undesirable plants, such as trees, bushes, broad- leaved plants, grasses sedges, aquatic plants, and parasitic flowering plants.

The following types of weed damage have been found:

- ⇒ Compete the crop for essential plant nutrients, moisture and light
- ⇒ Create harvest problem
- ⇒ Reduced quality of crop products
- ⇒ Serve as alternative host for diseases causing agents and insects
- ⇒ Losses from increased cost of production.
- ⇒ Reduced land value and limited crop choice.
- ⇒ Reduction of yield

Only in some ways may weeds be beneficial:

- ❖ Weeds reduce soil and nutrient losses from erosion and leaching when the land is bare of crops.
- ❖ Weeds provide feed and cover for wild life and
- ❖ Weeds add organic matter in to the soil.

Weed control methods

I. **Preventive methods**: land preparation, seed cleaning, field sanitation, proper quarantine, and regulation of contaminated crop seeds.

II. **Crop competition**: to be competitive or smoother crop, the crop must be vigorous and fast growing.

III. **Physical**: hand-weeding, tillage, mowing, burning, hoeing, flooding, and mulching

IV. **Biological methods:**

   a. Natural enemy (fungus or insects ,vertebrates)
   b. Resistance species (allelopathy)

V. **Chemical methods**: using herbicides. , herbicides may be classified based on:

- **Nature of damage**

a. Non selective herbicides: kill all plants when applied at adequate rates e.g. 2, 4-D

b. Selective herbicides: kill or stunt weeds in a germinations or growing crop without harming the crop e.g. Gram axon.

- **Time of application**

  a. Pre emergence- systemic herbicides e.g. soil- acting herbicides

  b. Post emergence – selective herbicides e.g. sprays of 2, 4-D in cereals.

It is very important to know which wed flora or weed species occur in a given area in order to establish appropriate weed control program. Important weed species of cultivated land in Ethiopia are Amaranthus, Cuscuta, cyperus species, Digitaria, Avena, Orobanche, Striga hermonthica etc.

5.4.2. Insect pests

Insecta (insects) are arthropods that have small size, three body regions (head, thorax and abdomen), three pairs of legs , a pair of antenne and they feed by mandibles. Most insects are beneficial, others are considered as the most common crop pests.

a. **Beneficial insects:** Pollinators (e.g. Bees, wasps), Parasitoids (e.g.Tricograma on stalk borer), and Predators (e.g. Lady Bird beetle on aphids).

b. **Harmful insects:** Field pests (e.g. army worm), Storage pests-(weevils, flour moths), and Vectors (leaf hopper, aphids).

The major economic insect pests in Ethiopia are African boll worm, cereal stem borer, Red teff worm, sorghum chafer, wello bush cricket, Aphids, Army worm, weevils, flour moths etc.

5.4.3. Plant disease

Disease is harmful deviation from the normal function of physiological process of an organism. Crop diseases cause yield reduction. Plant disease may be classified into two categories on the basis of causal agent:

a. **Abiotic (noninfectious) disease:** caused by environmental factor and thus not infectious. E.g. abnormal levels of growth requirement (high, low or extreme).

b. **Biotic (Infectious) disease: -** caused by pathogen and can be transmitted. The organisms are fungus, bacteria, nematodes and viruses, parasitic higher plants.

The interaction between the causal organism (Pathogen), host and certain factors within the environment and these factors form what is called the **Disease triangle**. Disease will occur only when the pathogen interacts with a susceptible host under favorable conditions. The presence of a pathogen alone is not sufficient to cause disease. The most serious crop diseases in Ethiopia e.g. Rust, Smut, Leaf blight, Root rot, powdery mildew, Damping off. etc.

Control measure: Exclusion of pathogen (quarantine), Eradication of pathogen, Use of resistance variety, and protecting susceptible host uses these various methods either separately or in combination (Integration).

Integrated Pest Management (IPM): is a pest management strategy that is socio- economic context of farming systems, the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible manner as possible, and maintains the pest population level below those causing economic injury (Dent, 1991). The economic injury level is the lowest population density that will cause economic damage. The ultimate objective of IPM is to reduce dependence on chemical control as the main input for crop protection.

Components of IPM:

1. **Quarantine measures:** Is enforcement of laws against establishment of exotic pests by exercising phyto sanitary inspection at points of entry to an area of interest.
2. **Host plant resistance**. resistant cultivars
3. **Cultural control: refers** to the use of management practices that make the environment less favorable to pest reproduction, dispersal and/ or survival .e.g. time of panting, site selection, crop rotation, seeding and planting methods, crop residue and alternative host destruction, tillage practices and appropriate cropping system, fertilizer and water management.
4. **Mechanical and physical control methods**: these methods are measures that are taken to destroy pests or make the environment less favorable for their entry, reproduction, dispersal and / or survival. These methods include manual collection and destruction of insect pests, mechanical exclusion of pests by means of nets, ditches, fences and traps.
5. **Interference methods**-the use of semio chemicals, the sterile insect and use of insect growth regulators are loosely grouped together under the common theme of interference methods.
6. **Biological control methods**-use of natural enemies namely predators, parasitoids, pathogen to maintain the density of pest species at lower densities than could occur in their absence.

7. **Chemical control**- refers to the use of pesticides for the control of agricultural pest.
8. **Botanical and animal products** –use available botanical and animal products are very important for controlling of pests. This integrated pest management strategy should be reached to crop producers/ growers through extension service.

5.5 Harvesting, storage & Marketing

Harvesting

For successful and efficient harvesting of a crop, it is desirable to know:

- When to harvest
- How to harvest
- How to minimize loss during harvest

Maturity and time of harvest

The best time to harvest a crop depends on: type economic yield, utilization of product, and storage methods, moisture content and environmental factors. Harvesting should be done when the grains fully mature and dry. Early harvesting causes yield loss in quantity and quality due to disease attack and shrinkage of grains whereas late harvesting may cause yield reduction due to shattering and lodging and pest attack etc.

- **Physiological maturity:** – the stage of development of the product at which maximum dry weight has been attained by the plant and consequently no gains in product yield can occur with increased production inputs. At physiological maturity, translocation of photosynthetic to economic parts (grain) is stopped and moisture content drops up to 20%. It is advantageous to harvest the crops at physiological maturity, which can be judged by external symptoms of crop s like yellowing of leaves, drying of pod and bursting of grains or pods.
- **Harvest maturity**: - The stage of harvesting a product to obtain peak quality and quantity, as determined by the producer. Generally, the market and botanical maturity are identical in cereal crops but vegetable crops they are not.

How to harvest

- Generally they are two types of harvesting.
    - Hand harvesting
    - Mechanical harvesting

Methods of Harvesting: It is the processes of collecting various plant produces, whenever they are ready for utilization or marketing.

- Collecting grains and fruits of various crops
- Picking up cotton fibers, tobacco leaves, flower
- Digging of root and tuber crops

Harvest losses

- It can be due to
  - Harvesting techniques
  - Harvesting time

Storage

It is very important factor specially in horticulture crops, due to the fact that , their produce is highly perishable and not storable for a longer time, since they continue their respiration (exchange of gases) and transpiration (water release) processes even after harvest, all the expense of their own reserve food and mixture .

Important condition for safe grain storage:-

- Low moisture content of products (8-15%)
- Low temperature in the store to suppress pathogens and insects
- Good aeration to facilitate moisture loss
- Appropriate protection of the product from rain, insect pest and rodents

The storage structure and grain container should be well treated and cleaned

- After harvest, products will go directly to:
  - Consumption
  - Markets
  - Commercial storage
  - On-farm storage
- Crops are stored from a few hours to several years depending on:
  - Type of crop
  - Storage condition
  - Purpose of storage
- Reasons for storage include:
  - To balance periods of plenty against periods of scarcity

- ❖ To make the products available the whole year round
- ❖ To use for coming seeding
- ❖ To improve quality
- ❖ Delay marketing of a crop until prizes rise

➢ Shelf life of a crop during storage depends:

- ❖ initial quality of the crop
- ❖ storage stability
- ❖ external conditions

➢ In general, we can group the storage structures in to two:

1. Structure which requires refrigeration
   - ❖ Refrigerated storage
   - ❖ Controlled atmosphere storage
2. Traditional storage without refrigeration
   - ❖ Earthen pots, baskets, sacks, bags
   - ❖ Underground storage

Marketing of Agricultural Crops

➢ Marketing: - getting the products to the consumer

➢ Agricultural marketing – is a process by which the producers and buyers of agricultural goods are brought together

➢ Buyer of agricultural crops can be divided in to three main categories:

1. Those who purchase agricultural crops for direct consumption
2. Those who demand agricultural crops for use as intermediate crops
3. Those who buy agricultural crops for sending them abroad

➢ Marketing of agricultural crops is more complicated than marketing of other non agricultural goods for the following reasons:

- ❖ Production characteristics (small scale, scattered, seasonal)
- ❖ Product characteristics (more bulky and less value; perishable; varying, uncertain quality and quantity; elastic supply)
- ❖ Consumption characteristics (continuous, regular and in small quantity, inelastic demand)