Agriculture – Definition – Importance and scope - Branches of agriculture - Evolution of man and agriculture – Development of scientific agriculture - National and International Agricultural Research Institutes.

Agriculture

The term Agriculture is derived from two Latin words **ager** or **agri** meaning **soil** and **cultura** meaning **cultivation**. Agriculture is an applied science which encompasses all aspects of crop production including horticulture, livestock rearing, fisheries, forestry, etc.

Agriculture is defined as an art, science and business of producing crops and livestock for economic purposes.

As an art it embraces knowledge of the way to perform the operations of the farm in a skillful manner, but does not necessarily include an understanding of the principles underlying the farm practices.

As a science: utilizes all technologies developed on scientific principles such as crop breeding, production techniques, crop protection, economics etc. to maximize the yield and profit. For example, new crops and varieties developed by hybridization, Transgenic crop varieties resistant to pests and diseases, hybrids in each crop, high fertilizer responsive varieties, water management, herbicides to control weeds, use of bio-control agents to combat pest and diseases etc.

As the business: As long as agriculture is the way of life of the rural population production is ultimately bound to consumption. But agriculture as a business aims at maximum net return through the management of land labour, water and capital, employing the knowledge of various sciences for production of food, feed, fibre and fuel. In recent years, agriculture is commercialized to run as a business through mechanization.

AGRICULTURE is defined in the Agriculture act (1947), as including 'horticulture, fruit growing, seed growing, dairy farming and livestock breeding and keeping, the use of land as grazing land, meadow land, osier land, market gardens and nursery grounds, and the use of land for woodlands where that use ancillary to the farming of land for Agricultural purposes".

SCOPE AND IMPORTANCE OF AGRICULTURE IN INDIA AND TAMILNADU

- With a 16% contribution to the gross domestic product (GDP), agriculture still provides livelihood support to about two-thirds of country's population.
- The sector provides employment to 58% of country's work force and is the single largest private sector occupation.
- Agriculture accounts for about 15% of the total export earnings and provides raw material to a large number of Industries (textiles, silk, sugar, rice, flour mills, milk products).
- Rural areas are the biggest markets for low-priced and middle-priced consumer goods, including consumer durables and rural domestic savings are an important source of resource mobilization.
- The agriculture sector acts as a wall in maintaining food security and in the process, national security as well.
- The allied sectors like horticulture, animal husbandry, dairy and fisheries, have an important role in improving the overall economic conditions and health and nutrition of the rural masses.
- To maintain the ecological balance, there is need for sustainable and balanced development of agriculture and allied sectors.

- Agriculture's eyes and minds are soothed by dynamic changes from brown (bare soil) to green (growing crop) to golden (mature crop) and bumper harvests.
- Plateauing of agricultural productivity in irrigated areas and in some cases the declining trend warrants attention of scientists.

Agriculture helps to elevate the community consisting of different castes and communities to a better social, cultural, political and economical life. Agriculture maintains a biological equilibrium in nature. Satisfactory agricultural production brings peace, prosperity, harmony, health and wealth to individuals of a nation by driving away distrust, discord and anarchy.

REVOLUTIONS IN AGRICULTURE

- Through white revolution, milk production quadrupled from 17 million tonnes at independence to 108.5 million tonnes.
- Through blue revolution, fish production rose from 0.75 million tonnes to nearly 7.6 million tonnes during the last five decades.
- Through yellow revolution oil seed production increased 5 times (from 5 million tonnes to 25 million tonnes) since independence.
- Similarly, the egg production increased from 2 billion at independence to 28 billion, sugarcane production from 57 million tonnes to 282 million tonnes, cotton production from 3 million bales to 32 million bales which shows our sign of progress.
- India is the largest producer of fruits in the world. India is the second largest producer of milk and vegetable.

BRANCHES OF AGRICULTURE

Seven branches viz.,

1. Agronomy
2. Horticulture
3. Forestry
4. Animal husbandry
5. Fishery science
6. Agricultural Engineering and
7. Home science

1) Agronomy – Deals with the production of various crops which includes food crops, fodder crops, fibre crops, sugar, oilseeds, etc. The aim is to have better food production and how to control the diseases.

2) Horticulture - Deals with the production of fruits, vegetables, flowers, ornamental plants, spices, condiments and beverages.

3) Forestry – Deals with production of large scale cultivation of perennial trees for supplying wood, timber, rubber, etc. and also raw materials for industries.

4) Animal husbandry – Deals with agricultural practice of breeding and raising livestock in order to provide food for humans and to provide power (draught) and manure for crops.

5) Fishery science – Deals with practice of breeding and rearing fishes including marine and inland fishes, shrimps, prawns etc. in order to provide food, feed and manure.

6) Agricultural Engineering – Deals with farm machinery for filed preparation, inter-cultivation, harvesting and post harvest processing including soil and water conservation engineering and bio-energy.

7) Home Science – Deals with application and utilization of agricultural produces in a better manner in order to provide nutritional security, including value addition and food preparation.

On integration, all the seven branches, first three is grouped as for crop production group and next two animal management and last two allied agriculture branches.3

Evolution of man and Agriculture

There are different stages in development of agriculture, which is oriented with human civilization. They are Hunting Pastoral Crop culture Trade (stages of human civilization).

1. Hunting – It was the primary source of food in old days. It is the important occupation and it existed for a very long period.

2. Pastoral – Human obtained his food through domestication animals, e.g. dogs, horse, cow, buffalo, etc. They lived in the periphery of the forest and they had to feed his domesticated animals. For feeding his animals, he would have migrated from one place to another in search of food. It was not comfortable and they might have enjoyed the benefit of staying in one place near the river bed.

3. Crop culture - By living near the river bed, he had enough water for his animals and domesticated crops and started cultivation. Thus he has started to settle in a place.

4. Trade – When he started producing more than his requirement the excess was exchanged, this is the basis for trade. When agriculture has flourished, trade developed. This lead to infrastructure development like road, routes, etc.

Agriculture became civilized from crop culture stage. Some important events for different periods that lead to development of scientific agriculture.

Period	Events
Earlier than 10000 BC	Hunting & gathering
7500 BC	Cultivation of crops- Wheat & Barley
3400 BC	Wheel was invented
3000 BC	Bronze used for making tools
2900 BC	Plough was invented, irrigated farming started
2300 BC	Cultivation of chickpea, cotton, mustard
2200 BC	Cultivation of rice
1500 BC	Cultivation of sugarcane
1400 BC	Use of iron
1000 BC	Use of iron plough
1500 AD	Cultivation of orange, brinjal, pomegranate
1600 AD	Introduction of several crops to India i.e. potato, tapioca, tomato, chillies, pineapple, groundnut, tobacco, rubber, American cotton

Indian agriculture - Indian economy – National income – per capita income – Agricultural income in GDP -Women in agriculture and empowerment

Indian Agriculture and Economy:

Indian Agriculture is one of the most significant contributors to the Indian economy. Agriculture is the only means of living for almost 60% of the employed class in India. The agriculture sector of India has occupied almost 43% of India's geographical area. Agriculture is still the only largest contributor to India's GDP (16%) even after a decline in the same in the agriculture share of India. Agriculture also plays a significant role in the growth of socio-economic sector in India.

In the earlier times, India was largely dependent upon food imports, but the successive story of the agriculture sector of Indian economy has made it self-sufficing in grain production. The country also has substantial reserves for the same. India depends heavily on the agriculture sector, especially on the food production unit after the 1960 crisis in food sector. Since then, India has put a lot of effort to be self-sufficient in the food production and this endeavour of India has led to the Green Revolution. The Green Revolution came into existence with the aim to improve the agriculture in India.

The services enhanced by the Green Revolution in the agriculture sector of Indian economy are as follows:

- Acquiring more area for cultivation purposes
- Expanding irrigation facilities
- Use of improved and advanced high-yielding variety of seeds

- Implementing better techniques that emerged from agriculture research
- Water management
- Plan protection activities through prudent use of fertilizers, pesticides.

All these measures taken by the Green Revolution led to an alarming rise in the wheat and rice production of India's agriculture. Considering the quantum leap witnessed by the wheat and rice production unit of India's agriculture, a National Pulse Development Programme that covered almost 13 states was set up in 1986 with the aim to introduce the improved technologies to the farmers. A Technology Mission on Oilseeds was introduced in 1986 right after the success of National Pulse Development Programme to boost the oilseeds sector in Indian economy. Pulses too came under this programme. A new seed policy was planned to provide entree to superior quality seeds and plant material for fruits, vegetables, oilseeds, pulses and flowers.

The Indian government also set up Ministry of Food Processing Industries to stimulate the agriculture sector of Indian economy and make it more lucrative. India's agriculture sector highly depends upon the monsoon season as heavy rainfall during the time leads to a rich harvest. But, the entire year's agriculture cannot possibly depend upon only one season. Taking into account this fact, a second Green Revolution is likely to be formed to overcome such restrictions. An increase in the growth rate and irrigation area, improved water management, improving the soil quality and diversifying into high value outputs, fruits, vegetables, herbs, flowers, medicinal plants and bio-diesel are also on the list of the services to be taken by the Green Revolution to improve the agriculture in India.

National income

National Income is important because of the following reasons,

- To see the economic development of the country.
- To assess the developmental objectives.
- To know the contribution of the various sectors to national income.

Internationally some countries are wealthy, some countries are not wealthy and some countries are in-between. Under such circumstances, it would be difficult to evaluate the performance of an economy. Performance of an economy is directly proportionate to the amount of goods and services produced in an economy. Measuring national income is also important to chalk out the future course of the economy. It also broadly indicates people’s standard of living. Income can be measured by Gross National Product (GNP), Gross Domestic Product (GDP), Gross National Income (GNI), Net National Product (NNP) and Net National Income (NNI). The Indian economy is the 12th largest in USD exchange rate terms. India is the second fastest growing economy in the world. India’s GDP has touched US$1.25 trillion. The crossing of Indian GDP over a trillion dollar mark in 2007 puts India in the elite group of 12 countries with trillion dollar economy. The tremendous growth rate has coincided with better macroeconomic stability. India has made remarkable progress in information technology, high end services and knowledge process services.

Agricultural income in GDP

Agriculture sector contributed 32% in 1990-91, 20% during 2005-06 and around 16% now. Though the contribution of agriculture to the GDP income of India, it is great news that today the service sector is contributing more than half of the Indian GDP. It takes India one step closer to the developed economies of the world. Earlier it was agriculture which mainly contributed to the Indian GDP. The Indian government is still looking up to improve the GDP of the country and so

several steps have been taken to boost the economy. Policies of FDI, SEZs and NRI investment have been framed to give a push to the economy and hence the GDP.

Agriculture per capita income

The per capita income of the agriculture sector declines to 1/3 of the national per capita income during the recent years. The per capita income of the agriculture population is estimated around Rs. 10,865 in 2010, which is around 32% of the national per capita income at Rs. 33,802/-. Per capita income of the agriculture population was around half (1/2) at Rs. 5,505 of the national per capita income at Rs. 11,433/- during 1980 however, it came down to around 42% at Rs. 6,652/- of the national per capita income at Rs. 16,020/- during 2000.

Income Distribution in Agriculture sector Year/ Period	Agriculture Share in GDP	Population Dependent on Agriculture	Agriculture Per Capita (in Rs.)
1980	39	70	4745 (56%)
1990	31	65	5505 (48%)
2000	25	59	6652 (42%)
2010	16	58	10865 (32%)

Women in Agriculture and empowerment

Women in India now participate in all activities such as education, sports, politics, media, art and culture, service sectors, science and technology, etc. Indira Gandhi, who served as Prime Minister of India for an aggregate period of fifteen years is the world's longest serving woman Prime Minister.

The Constitution of India guarantees to all Indian women equality (Article 14), no discrimination by the State [Article 15(1)], equality of opportunity (Article 16) and equal pay for equal work [Article 39(d)]. In addition, it allows special provisions to be made by the State in favour of women and children [Article 15(3)], renounces practices derogatory to the dignity of women [Article 51(a) (e)], and also allows for provisions to be made by the State for securing just and humane conditions of work and for maternity relief. (Article 42).

The feminist activism in India picked up momentum during later 1970s. Since alcoholism is often associated with violence against women in India, many women groups launched anti-liquor campaigns in Andhra Pradesh, Himachal Pradesh, Haryana, Orissa, Madhya Pradesh and other states. Many Indian Muslim women have questioned the fundamental leaders' interpretation of women's rights under the Shariat law and have criticized the triple talaq system.

In 1990s, grants from foreign donor agencies enabled the formation of new women-oriented NGOs. Self-help groups and NGOs such as Self Employed Women's Association

(SEWA) have played a major role in women's rights in India. Many women have emerged as leaders of local movements. For example, Medha Patkar of the Narmada Bachao Andolan.

The Government of India declared 2001 as the Year of Women's Empowerment (*Swashakti*). The National Policy for the Empowerment of Women came was passed in 2001.

In 2006, the case of a Muslim rape victim called Imrana was highlighted in the media. Imrana was raped by her father-in-law. The pronouncement of some Muslim clerics that Imrana should marry her father-in-law led to widespread protests and finally Imrana's father-in-law was given a prison term of 10 years, The verdict was welcomed by many women's groups and the All India Muslim Personal Law Board.

In 2010 March 9, one day after International Women's day, Rajyasabha passed Women's Reservation Bill, ensuring 33% reservation to women in Parliament and state legislative bodies.

Women empowerment would become more relevant if women are educated, better informed and can take rational decisions. It is also necessary to sensitize the other sex towards women. It is important to usher in changes in societal attitudes and perceptions with regard to the role of women in different spheres of life. Adjustments have to be made in traditional gender specific performance of tasks. A woman needs to be physically healthy so that she is able to take challenges of equality. But it is sadly lacking in a majority of women especially in the rural areas. They have unequal access to basic health resources.

Most of the women work in agricultural sector either as workers, in household farms or as wageworkers. Yet it is precisely livelihood in agriculture that has tended to become more volatile and insecure in recent years and women cultivators have therefore been negatively affected. The government's policies for alleviating poverty have failed to produce any desirable results, as women do not receive appropriate wages for their labour. There is also significant amount of unpaid or non-marketed labor within the household. The increase in gender disparity in wages in the urban areas is also quite marked as it results from the employment of women in different and lower paying activities. They are exploited at various levels. They should be provided with proper wages and work at par with men so that their status can be elevated in society.

There is no doubt about the fact that development of women has always been the central focus of planning since Independence. Empowerment is a major step in this direction but it has to be seen in a relational context. A clear vision is needed to remove the obstacles to the path of women's emancipation both from the government and women themselves. Efforts should be directed towards all round development of each and every section of Indian women by giving them their due share.

History of agricultural development in the world and India. Agriculture heritage – Agriculture in ancient India

History of agricultural development in the world and India

Please refer Lecture 1 theory notes.

Agriculture heritage

History is the continuous record of past events

Heritage is the inherited values carried from one generation to other generation

Agricultural heritage refers to the values and traditional practices adopted in ancient India which are more relevant for present day system.

Agriculture Heritage in India

Agriculture in India is not of recent origin, but has a long history dating back to Neolithic age of 7500-6500 B.C. It changed the life style of early man from ‘nomadic hunter of wild berries and roots’ to ‘cultivator of land’. Agriculture is benefited from the wisdom and teachings of great saints. The wisdom gained and practices adopted have been passed down through generations. The traditional farmers have developed the nature friendly farming systems and practices such as mixed farming, mixed cropping, crop rotation etc. The great epics of ancient India convey the depth of knowledge possessed by the older generations of the farmers of India. The modern society has lost sight of the importance of the traditional knowledge which had been subjected to a process of refinement through generations of experience. The

ecological considerations shown by the traditional farmers in their farming activities are now-a-days is reflected in the resurgence of organic agriculture.

The available ancient literature includes the four Vedas (rig, yajur, sama, atharvana), nineteen Brahmanas (A total of 19 Brahmanas are extant at least in their entirety: two associated with the Rigveda, six with the Yajurveda, ten with the Samaveda and one with the Atharvaveda.), Aranyakas, Sutra literature, Susruta Samhita, Charaka Samhita, Upanishads, the epices Ramayana and Mahabharata, Puranas (20), Buddhist and Jain literature, and texts such as Krishi-Parashara, Kautilya's Arthasastra, Panini's Ashtadhyayi, Sangam literature of Tamils, Manusmirti (laws), Varahamihira's Brihat Samhita (maths & astrology), Amarkosha, Kashyapiya-Krishisukti and Surapala's Vriskshayurveda. This literature was most likely to have been composed between 6000

BC to 1000 AD.

Rigveda is the most ancient literary work of India. It believed that Gods were the foremost among agriculturists. According to Amarakosha (a thesaurus of Sanskrit written by the Jain or Buddhist scholar Amarasimha**)**, Aryans were agriculturists. Manu and Kautilya prescribed agriculture, cattle rearing and commerce as essential subjects, which the king must learn. According to Patanjali (compiler of the Yoga Sūtras) the economy of the country depended on agriculture and cattle-breeding. Plenty of information is available in 'Puranas', which reveals that ancient Indians had intimate knowledge on all agricultural operations. Some of the well known ancient classics of India are namely, Kautilya's'Arthashastra'; Panini's 'Astadhyayi'; Patanjali's 'Mahabhasya'; Varahamihira's 'Brahat Samhita'; Amarsimha's 'Amarkosha' and Encyclopaedic works of Manasollasa. These classics testify the knowledge and wisdom of the people of ancient period. Technical books dealing exclusively with agriculture were Sage Parashara's 'Krishiparashara' in 1000 A.D. Other important texts are Agni Purana and Krishi Sukti attributed to Kashyap (500 A.D.). Ancient Tamil and Kannada works contain lot of useful information on agriculture in ancient India. Agriculture in India made tremendous progress in the rearing of sheep and goats, cows and buffaloes, trees and shrubs, spices and condiments, food and non-food crops, fruits and vegetables and developed nature friendly farming practices. These practices had social and religious undertones and became the way of life for the people. Domestic rites and festivals often synchronised with the four main agricultural operations of ploughing, sowing, reaping and harvesting.

In the Rigveda, there is reference to hundreds and thousands of cows; to horses yoked to chariots; to race courses where chariot races were held; to camels yoked to the chariots; to sheep and goats offered as sacrificial victims, and to the use of wool for clothing. The famous Cow Sukta indicates that the cow had already become the very basis of rural economy. In another Sukta, she is defined as the mother of the Vasus, the Rudras and the Adityas, as also the pivot of Immortality. The Vedic Aryans appear to have large forests at their disposal for securing timber, and plants and herbs for medicinal purposes appear to have been reared by the physicians of the age, as appears in the Atharva Veda. The farmers' vocation was held in high regard, though agriculture solely The information related to the biodiversity and agriculture (including animal husbandry) are available in these texts.

depended upon the

The four Vedas mention more than 75 plant species, Satapatha Bhrahamna mentions over 25 species, and Charkaa Samhita (300 BC) an Aayurvedic (Indian medicine) treatise-mentions more than 320 plants. Susruta (400 BC) records over 750 medicinal plant species. The oldest book, Rigveda (4000 BC) mentions a large number of poisonous and non poisonous aquatic and terrestrial, and domestic and wild creatures and animals. Puranas mention about 500 species of plants. The science of arbori-horticulture had developed well and has been documented in Surapala's Vrikshayurveda. Forests were very important in ancient times. From the age of Vedas, protection of forests was emphasized for ecological balance. Kautilya in his Artha Sastra (321-296 BC) mentions that superintendent of forests had to collect forest produce through the forest guards. He provides a long list of trees, varieties, of bamboos, creepers, fibrous plants, drugs and poisons, skins of various animals, etc., that come under the purview of this officer.

The preservation of wild animals was encouraged and hunting as a sport was regarded as detrimental to proper development of the character and personality of the ruler, according to Manu (Manusmriti, 2nd Century BC). Specifically, in the Puranas (300-750 AD) the names of Shalihotra on horses and Palakapya on elephants have been found as experts in animal husbandry. For instance, Garudapurana is a text dealing with treatment of animal disorders while the classical work on the treatment of horses is Aswashastra. One chapter in Agnipurana deals with the treatment of livestock and another on treatment of trees.favours of Parjanya, the god of rain. His thunders are described as food-bringing. The four Vedas mention more than 75 plant species, Satapatha Bhrahamna mentions over 25 species, and Charkaa Samhita (300 BC) an Aayurvedic (Indian medicine) treatise-mentions more than 320 plants. Susruta (400 BC) records over 750 medicinal plant species. The oldest book, Rigveda (4000 BC) mentions a large number of poisonous and non poisonous aquatic and terrestrial, and domestic and wild creatures and animals. Puranas mention about 500 species of plants. The science of arbori-horticulture had developed well and has been documented in Surapala's Vrikshayurveda. Forests were very important in ancient times. From the age of Vedas, protection of forests was emphasized for ecological balance. Kautilya in his Artha Sastra (321-296 BC) mentions that superintendent of forests had to collect forest produce through the forest guards. He provides a long list of trees, varieties, of bamboos, creepers, fibrous plants, drugs and poisons, skins of various animals, etc., that come under the purview of this officer.

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Stages of agriculture development - Era of civilization- Importance of Neolithic civilization

Stages of agriculture development

12000 to 9500 years ago

- Hunters and food-gathers stage existed.
- Stone implements (microliths) were seen throughout the Indian subcontinent.
- Domestication of dog occurred in Iraq.
- Earliest agriculture was by vegetative propagation (e.g., bananas, sugarcane, yam, sago, palms, and ginger).

9500 to 7500 years ago

- Wild ancestors of wheat and barley, goat, sheep, pig, and cattle were found.

7500 to 5000years ago

- Significant features were invention of plough, irrigated farming, use of wheel, and metallurgy and in Egypt, seed dibbling said to be practiced.

5000to 4000years ago

- Harappan culture is characterized by cultivation of wheat, barley and cotton; plough agriculture and bullocks for drought. Indus Valley is the home of cotton.
- Wheeled carts were commonly used in the Indus valley.
- Harappans not only grew cotton but also devised methods for ginning / spinning / weaving.

4000 to 2000years ago

- In North Arcot, bone / stone tools were found.
- In Nevasa (Maharastra), copper and polished stone axes were used. First evidence of the presence of silk was found at this location.
- At Navdatoli on Narmada river (Nemar, Madhya Pradesh), sickles set with stone teeth were used for cutting crop stalks. Crops grown were wheat, linseed, lentil, urd (black gram), mung bean, and khesari.
- In Eastern India, rice, bananas, and sugarcane were cultivated.

2000-1500 years ago

- Tank irrigation was developed and practiced widely.

- Greek and Romans had trade with South India; pepper, cloth, and sandal wood were imported by Romans.
- Chola King Karikala (190 AD) defeated Cheras and Pandyas, invaded Srilanka, captured 12000 men and used them as slaves to construct an embankment along the Cauvery, 160km along, to protect land from floods. He has built numerous irrigation tanks and promoted agriculture by clearing forests.

1500-1000 years ago

The Kanauj Empire of Harshavardhana (606-647 AD)

- Cereals such as wheat, rice and millets, and fruits were extensively grown. A 60-day variety and fragrant varieties of rice are mentioned.
- Ginger, mustard, melons, pumpkin, onion, and garlic are also mentioned.
- Persian wheel was used in Thanesar (Haryana).

The kingdoms of South India

- The kingdoms were of the Chalukyas (Badami), Rashtrakutas (Latur), Pallavas (Kanchi), Pandyas, Hoysals (Helebid), and Kakatiyas (Warangal).
- Cholas ushered in a glorious phase in South Indian in the 10^{th} century AD.
- New irrigation systems for agriculture were developed- chain tanks in Andhra in the 9^{th} century; and 6.4 km Kaveripak bund.
- Cholas maintained links with China, Myanmar, and Campodia.
- The tank supervision committee (Eri-variyam) looked after the maintenance of a village and regulated the water supply.

1000-700 years ago

- Arab conquest of Sind was during 711-712 AD; Md bin Qaism defeated Dahir, the Hindu king of Sind. Arabs were experts in gardening.
- 1290- 1320AD (Reign of Khiljis): Alauddin Khilji destroyed the agricultural prosperity of a major part of India. He believed in keeping the farmers poor.

Era of civilization

It is supposed that man was evolved on earth about 1.7 million years ago. This man was evolved from the monkey who started to move by standing erect on his feet. Such man has been called *Homo erectus* (or) Java man (or) Peking man. Later on Java man transformed into Cro-Magnon and Cro-Magnon into modern man. The modern man is

zoologically known as *Homo sapiens* (Homo - Continuous, Sapiens - learning habit). A primitive form of *Homo sapiens*, called Neanderthal man (*Homo sapiens neanderthalensis*), was common in Europe and Asia. After the last glacial period (about 10,000 years ago), modern *Homo sapien sapiens*, began to spread all over the globe.

In the beginning such man had been spending his life wildly, but during the period 8700-7700 BC, they started to pet sheep and goat, although the first pet animal was dog, which was used for hunting. The history of agriculture and civilization go hand in hand as the food production made it possible for primitive man to settle down in selected areas leading to formation of society and initiation of civilization. The development of civilization and agriculture had passed through several stages. Archeologist initially classified the stages as stone age, Bronze and Iron age. Subsequently the scholars spilt up the stone age into Paleolithic period (old stone age), Neolithic age (New stone age) and Mesolithic age (Middle stone age).

Each of three ages, saw distinct improvements. The man fashioned and improved tools out of stones, bones, woods etc. to help them in day-to-day life. They started growing food crops and domesticated animals like cow, sheep, goat, dog etc.

I. The Stone Age culture : (2,50,000 Bc to 3500 BC)

The stone age is divided into three periods

A. Palaeolithic period (old stone age)
B. Mesolithic period (middle stone age)
C. Neolithic period (new stone age)

A. Paleolithic age : Hunters and food gatherers (2,50,000 to 10,000 BC)

This period is characterized by the food gatherers and hunters. The stone age man started making stone tools and crude choppers. The chipped stone tools and chopped pebbles were used for hinting, cutting and other purposes. He had no knowledge on cultivation and house building.

The Palaeolithic age in India is divided into three phases according to the nature of stone tools used by the people and according the nature of climate

a) Early or lower palaeolithic (2,50,000 to 1,00,000 BC)
b) Middle palaeolithic (1,00,000 to 40,000 BC)

c) Upper palaeolithic (40,000 to 10,000 BC)

B. Mesolithic period : Hunters and Herders (10,000 to 3,700 BC)

The transitional period between the end of the Paleolithic and beginning of the Neolithic is called Mesolithic. It began about 10000BC and ended with the rise of agriculture. This period is characterized by tiny stone implements called microliths. The Mesolithic people lived on hunting, fishing and good-gathering. At later stages, they also domesticated animals. The domestication of the dog was the major achievement of the Mesolithic hunter.

C. Neolithic Age : Food producers (The beginning of Agriculture)

The Neolithic age began between 9000 to 7500 BC. Neolithic revolution occurred in Western Asia between 9500 and 8500 years ago mainly in the **Fertilie Cresent** (hilly regions embracing Israel, Jordon, Turkey, Iran, Caspian basin and adjoining Iranian plateau). Neolithic revolution brought a major change in the techniques of food production which gave man control over his environment and saved him from the precarious existence of mere hunting and gathering of wild berries and roots. For the first time, he lived in **settled villages** and apart from security from hunger he had leisure time to think and contemplate.

The main features of Neolithic culture in India

1. Neolithic culture denotes a stage in economic and technological development in India
2. Use of polished stone axes for cleaning the bushes
3. Hand made pottery for storing food grains
4. Invented textile, weaving and basketry
5. Cultivation of rice, banana sequence and yams in eastern parts of India
6. Cultivation of millets and pulses in south India
7. Discovery of silk

II. Bronze Age (Chalcolithic culture) (3000-1700 BC):

The end of the Neolithic period saw the use of metal. The metal to be used first was copper. The term Chalcolithic (stone – copper phase) is applied to communities using stone implements along with copper and bronze. In more advanced communities,

the proportion of copper and bronze implements is higher than that of stones. The chalcolithic revolution began in Mesopotamia in the fourth millennium B.C. from this area it spread to Egypt, and Indus valley.

The significant features are

1. Invention of plough
2. Agriculture shifted from hilly area to lower river valley
3. Flood water were stored for irrigation and canals were dug
4. Irrigated farming started in this period
5. Sowing of seed by dibbling with a pointed stick
6. Use of wheel.
7. Salinity problem and water logging were noticed due to canal irrigation.

III. The Iron Age

The Iron phase in India started after the advent of Aryans. Aryan land was called ***Saptasindhava*** i.e. the land of seven rivers (Sutlej, Beas, Ravi, Chenab, Jhelum, Sindhu and Saraswati). Aryans settle along the rivers.

The salient features of iron age are

- The harvesting tool used was **sickle**.
- The crops grown were mainly sesame and sugarcane.
- Iron plough, shear, axe, sickles and hoes were used
- The domestic animals were sheep, goats, dogs, mule, tortoise, cattle breeds and elephants.

Chronology of Agricultural technology development in India

Agriculture in India is broadly classified in to five different periods before India's independence.

1. Early history (Before 15000 BCE)
2. Vedic period – Post Maha Janapadas period (1500 BCE – 200 CE)
3. Early Common Era – High Middle Ages (200–1200 CE)
4. Late Middle Ages – Early Modern Era (1200–1757 CE)
5. Colonial British Era (1757–1947 CE)

[Note: BCE - short for "Before the Common Era", "Before the Christian Era", or "Before the Current Era". CE - Common Era, Current Era (Christian Era is, however, also abbreviated AD, for *Anno Domini*]

Indian agriculture began by 9000 BCE as a result of early cultivation of plants and domestication of crops and animals. Settled life soon followed with implements and techniques being developed for agriculture. Double monsoons led to two harvests being reaped in one year. Indian products soon reached the world via existing trading networks and foreign crops were introduced to India. Plants and animals; considered essential to their survival by the Indians, came to be worshiped and venerated. The middle ages saw irrigation channels reach a new level of sophistication in India and Indian crops affecting the economies of other regions of the world under Islamic patronage. Land and water management systems were developed with an aim of providing uniform growth. Despite some stagnation during the later modern era the independent Republic of India was able to develop a comprehensive agricultural program.

1. Early history (Before 1500 BCE)

• **9000 BCE:** Wheat and barley were domesticated in the Indian subcontinent. Domestication of horse, sheep and goat soon followed. This period also saw the first domestication of the elephant.

• **8000-6000 BCE:** Barley and wheat cultivation, along with the domestication of cattle, primarily sheep and goat—was visible in Mehrgarh (Balochistan, now in Pakistan). Agro pastoralism in India included threshing, planting crops in rows—either of two or of six—and storing grain in granaries.

• **5000 BCE:** Agricultural communities became widespread in Kashmir.

• **5000-4000 BCE:** Cotton was cultivated. The Indus cotton industry was well developed and some methods used in cotton spinning and fabrication continued to be practiced till the modern Industrialization of India. A variety of tropical fruit such as mango and muskmelon are native to the Indian sub-continent. The Indians also domesticated hemp, which they used for a number of applications including making narcotics, fibre and oil. The farmers of the Indus Valley grew peas, sesame, and dates. Sugarcane was originally from tropical South Asia and Southeast Asia. Different

species likely originated in different locations with *S. barberi* originating in India and *S. edule* and *S. officinarum* coming from New Guinea.
• **5440 BCE:** Wild *Oryza* rice appeared in the Belan and Ganges valley regions of northern India. Rice was cultivated in the Indus Valley civilization.
• **4500 BCE:** Irrigation was developed in the Indus Valley Civilization. The size and prosperity of the Indus civilization grew as a result of this innovation, which eventually led to more planned settlements making use of drainage.
• **3000 BCE**: Sophisticated irrigation and water storage systems were developed by the Indus Valley civilization, including artificial reservoirs at Girnar.
• **2600 BCE:** An early canal irrigation system from Circa.
• **2500 BCE:** Archeological evidence of an animal-drawn plough in the Indus Valley civilization
• **2000 BCE:** Agricultural activity included rice cultivation in the Kashmir and Harrappan regions.

2. Vedic period-Post Maha Janapadas period (1500 BCE–200 CE)

• Gupta (2004) finds it likely that summer monsoons may have been longer and may have contained moisture in excess than required for normal food production. One effect of this excessive moisture would have been to aid the winter monsoon rainfall required for winter crops.
• In India, both wheat and barley are held to be *Rabi* (winter) crops and—like other parts of the world—would have largely depended on winter monsoons before the irrigation became widespread. The growth of the *Kharif* crops would have probably suffered as a result of excessive moisture.
• Jute was first cultivated in India, where it was used to make ropes and cordage.
• Some animals—thought by the Indians as being vital to their survival—came to be worshiped.
• Trees were also domesticated, worshiped, and venerated—*Pipal* and *Banyan* in particular.
• Others came to be known for their medicinal uses and found mention in the holistic medical system *Ayurveda*.
• **1000–500 BCE:** There are repeated references to iron. Cultivation of a wide range of cereals, vegetables and fruits is described. Meat and milk products were part of the diet; animal husbandry was important. The soil was ploughed several times. Seeds were broadcasted. Fallowing and a certain sequence of cropping were recommended. Cow dung provided the manure. Irrigation was practiced.
• **322–185 BCE:** The Mauryan Empire categorized soils and made meteorological observations for agricultural use. Other Mauryan facilitation included construction and maintenance of dams, and provision of horse-drawn chariots—quicker than traditional bullock carts.
• **300 BCE:** The Greek diplomat Megasthenes, in his book *Indika*— provides a secular eyewitness account of Indian agriculture.

3. Early Common Era – High middle ages (200–1200 CE)

• The Tamil people cultivated a wide range of crops such as rice, sugarcane, millets, black pepper, various grains, coconuts, beans, cotton, plantain, tamarind and sandalwood. Jackfruit, coconut, palm, areca and plantain trees were also known.
• Systematic ploughing, manuring, weeding, irrigation and crop protection was practiced for sustained agriculture. Water storage systems were designed during this period.
• Kallanai (1st-2nd century CE), a dam built on river Kaveri during this period, is considered the as one of the oldest water-regulation structures in the world still in use.
• Spice trade involving spices native to India—including cinnamon and black pepper—gained momentum as India starts shipping spices to the Mediterranean.
• Roman trade with India followed as detailed by the archaeological record and the *Periplus of the Erythraean Sea*.
• Chinese sericulture attracted Indian sailors during the early centuries of the Common Era.
Sutlej Valley from Rampur ca. 1857
• **320-550 CE:** Crystallized sugar was discovered by the time of the Guptas and the earliest reference of candied sugar come from India.
• **647 CE:** Chinese documents confirm at least two missions to India, initiated in, for obtaining technology for sugar-refining.
• **875-1279 CE :** Noboru Karashima's research of the agrarian society in South India during the Chola Empire reveals that during the Chola rule land was transferred and collective holding of land by a group of people slowly gave way to individual plots of land, each with their own irrigation system.

• The growth of individual disposition of farming property may have led to a decrease in areas of dry cultivation.
• The Cholas also had bureaucrats which oversaw the distribution of water—-particularly the distribution of water by tank-and-channel networks to the drier areas.

4. Late middle ages – Early modern era (1200–1757 CE)

• The construction of water works and aspects of water technology in India is described in Arabic and Persian works. The diffusion of Indian and Persian irrigation technologies gave rise to irrigation systems which bought about economic growth and growth of material culture.
• Agricultural 'zones' were broadly divided into those producing rice, wheat or millets.
• Rice production continued to dominate Gujarat and wheat dominated north and central India.
• The Encyclopædia Britannica details the many crops introduced to India during this period of extensive global discourse.
• **1556-1605 CE:** Land management was particularly strong during the regime of Akbar the Great under whom scholar-bureaucrat Todarmal formulated and implemented elaborated methods for agricultural management on a rational basis.
• Indian crops—such as cotton, sugar, and citric fruits—spread visibly throughout North Africa, Islamic Spain, and the Middle East.
• Though they may have been in cultivation prior to the solidification of Islam in India, their production was further improved as a result of this recent wave, which led to far-reaching economic outcomes for the regions involved.[9]

5. Colonial British Era (1757–1947 CE)

• A number of irrigation canals are located on the Sutlej river.
• Few Indian commercial crops—such as Cotton, indigo, opium, and rice—made it to the global market under the British Raj in India.
• The second half of the 19th century saw some increase in land under cultivation and agricultural production expanded at an average rate of about 1% per year by the later 19th century.
• Due to extensive irrigation by canal networks Punjab, Narmada valley, and Andhra Pradesh became centers of agrarian reforms.
• The British regime in India did supply the irrigation works but rarely on the scale required.
• Community effort and private investment soared as market for irrigation developed.
• Agricultural prices of some commodities rose to about three times between 1870-1920.
• A rich source of the state of Indian agriculture in the early British era is a report prepared by a British engineer, Thomas Barnard, and his Indian guide, Raja Chengalvaraya Mudaliar, around 1774. This report contains data of agricultural production in about 800 villages in the area around Chennai in the years 1762 to 1766. This report is available in Tamil in the form of palm leaf manuscripts at Thanjavur Tamil University, and in English in the Tamil Nadu State Archives.
• 1871: Government of India created Department of Revenue, Agriculture and Commerce which formed as base for Initiation of Agriculture in India.
• 1880: Famine Commission Report was submitted which was base for inception of Agricultural Department.
• 1881: Separate Department of Agriculture at Centre for Famine relief operations
• 1890 : Dr. J.A. Voelcker appointed as a consulting chemist from Royal Agricultural Society (England) - Laid foundation for agricultural research in India.

• 1892 – 1903 - Appointment of Imperial Agricultural Chemist, Imperial Mycologist and Imperial Entomologist – Base for Beginning of inducting the scientist in Agriculture.
• 1901-05: To enhance agricultural education, Establishment of Agricultural Colleges at Pune, Kanpur, Sabour, Nagpur, Coimbatore and Lyallpur (Now in Pakistan).
• 1905: Establishment of Imperial Agricultural Research Institute (IARI) at Pusa (Bihar)
• 1929: Based on Royal Commission on Agriculture's recommendation (1928), Imperial Council of Agricultural Research (ICAR) was establishment to conduct comprehensive research.
• 1931-47: Indian Lac Cess Committee, Indian Central Tobacco Committee, Indian Central Oilseeds Committee were formed to improve research in various crops.

Republic of India (1947 CE onwards)

• Special programs were undertaken to improve food and cash crops supply.
• The Grow More Food Campaign (1940s) and the Integrated Production Programme (1950s) focused on food and cash crops supply respectively.
• 1957 : All India Coordinated Maize Improvement Project was initiated (First coordinated project) to exploit maize research (Specifically heterosis).
• Five-year plans of India—oriented towards agricultural development—soon followed.
• 1963: Introduction of semi dwarf wheat varieties from Bhakra Dam (completed in 1963) is the largest dam in India.
CIMMYT, Mexico Formed basis for green revolution.
• 1966: Introduced semi-dwarf rice varieties TN1 & IR 8 from Taiwan and Philippines respectively is formed as base for green revolution.
• Land reclamation, land development, mechanization, electrification, use of chemicals—fertilizers in particular, and development of agriculture oriented 'package approach' of taking a set of actions instead of promoting single aspect soon followed under government supervision.
• The many 'production revolutions' initiated from 1960s onwards included Green Revolution in India, Yellow Revolution (oilseed: 1986-1990), Operation Flood (dairy: 1970-1996), and Blue Revolution (fishing: 1973-2002) etc.
• 1979: National Agricultural Research Project (NARP) was launched to strengthen the research capabilities of SAUs
• Following the economic reforms of 1991, significant growth was registered in the agricultural sector, which was by now benefiting from the earlier reforms and the newer innovations of Agro-processing and Biotechnology.
• 1998: National Agricultural Technology Project (NATP) was initiated Strengthen the research on location specific problems Contract farming—which requires the farmers to produce crops for a company under contract—and high value agricultural product increased.
• 2006: National Agricultural Innovative Project (NAIP) was launched for End to end approach for solving problems.

Agronomy – definition – meaning and scope. Agro-climatic zones of India and Tamil Nadu – Agro ecological zones of India

Agronomy is derived from a Greek word '**agros'** meaning 'field' and '**nomos'** meaning 'management'. Principles of agronomy deal with scientific facts in relations to environment in which crop are produced.

Definition of Agronomy

1. It is defined as an agricultural science deals with principles and practices of crop production and field management.
2. Agronomy is branch of agricultural science, which deals with principles, & practices of soil, water & crop management.
3. It is branch of agricultural science that deals with methods which provide favorable environment to the crop for higher productively,

Boundaries and scale

Crop management, and its scientific study agronomy, are part of a system that comprises the physical elements of the climate, soil and land, the biological constituents of the vegetation and soil, the economic opportunities and constraints of markets, sales and profit, and the social circumstances and preferences of those who work the land.

Scope of Agronomy

Agronomy is a dynamic discipline with the advancement of knowledge and better understanding of planet, environment and agriculture. Agronomy science becomes imperative in Agriculture in the following areas.

- Identification of proper season for cultivation of wide range of crops is needed which could be made possible only by Agronomy science.
- Proper methods of cultivation are needed to reduce the cost of cultivation and maximize the yield and economic returns.
- Availability and application of chemical fertilizers has necessitated the generation of knowledge to reduce the ill-effects due to excess application and yield losses due to the unscientific manner of application.
- Availability of herbicides for control of weeds has led to development for a vast knowledge about selectivity, time & method of its application.
- Water management practices play grater role in present day crisis of water demand and Agronomy science answer to the questions 'how much to apply?' and 'when to apply?'.
- Intensive cropping is the need of the day and proper time and space intensification not only increase the production but also reduces the environmental hazards.
- New technology to overcome the effect of moisture stress under dry land condition is explored by Agronomy and future agriculture is depends on dry land agriculture.
- Packages of practices to explore full potential of new varieties of crops are the most important aspects in crop production which could be made possible only by Agronomy science.
- Keeping farm implements in good shape and utilizing efficient manner to nullify the present day labour crisis is further broadening the scope of agronomy.
- Maintaining the ecological balance through efficient management of crops, livestock and their feedings in a rational manner is possible only by knowing agronomic principles.
- Care and disposal of farm and animal products like milk and eggs and proper maintenance of accounts of all transactions concerning farm business is governing principles of agronomy.

Relation of agronomy to other sciences

Agronomy is a main branch of Agriculture. It is synthesis of several disciplines like soil science, Agricultural chemistry, crop physiology, plant ecology, biochemistry and economics.

- The Soil Science helps the agronomist to thoroughly understand the soil physical, chemical and biological properties to effect modification of the soil environment.
- The Agricultural Chemistry help the agronomist to understand the chemical composition and changes involved in the production, protection, and use of crops and livestock.
- The crop physiology helps to understand the basic life process of crops to understand functioning of each parts of plant to determine their input requirement like nutrients etc.
- The plant ecology helps us to understand the associated environment in which the crops grown like the influence of weather (Temperature, Rainfall etc).
- The biochemistry shows the way in which biochemical process takes place in crops which helps to understand critical requirements to favourably activate this process.
- The economics paves the way for profit and loss analysis in farming.

Role of Agronomist

Agronomist is a scientist who is dealing with the study of problems of crop production and adopting/recommending practices of better field crop production and soil management to get high yield and income.

- Agronomist aims at obtaining maximum production at minimum cost by exploiting the knowledge of the basic and applied sciences for higher crop production.
- In a broader sense, agronomist is concerned with production of food and fibre to meet the needs of growing population.
- He develops efficient and economic field preparation method for sowing crops in different season. (Flat bed, Ridges and furrows)
- He is also involved to selection of suitable crop and varieties to suit or to match varied seasons and soils. Eg. Red soil - groundnut, Black soil - cotton, Sandy soil – tuberous crops, Saline soil – Finger millet (*Ragi*). In *Kharif* if water is sufficient go for rice and water is not sufficient go for maize, sorghum.
- Evolves efficient method of cultivation (whether broadcasting, nursery and transplantation or dibbling, etc.) provides better crop establishment and maintain required population
- He has to identify various types of nutrients required by crops including time and method of application (e.g. for long duration rice (150-60-60 kg NPK), short duration: 120:50:50 kg NPK/ha Application P&K basal and N in three splits)
- Agronomist must select a better weed management practice. Either through mechanical or physical (by human work) or chemical (herbicides or weedicides, e.g. 2-4-D) or cultural (by having wide space it may increase weed growth by using inter space crops). Weeds are controlled by integrated weed management method also
- Selection of proper irrigation method, irrigation scheduling i.e. irrigation timing and quantity based on the crops to be irrigated, whether to irrigate continuously or stop in between and how much water to be supplied are computed by agronomy science so as to achieve maximum water use efficiency.
- Crop planning (i.e.) suitable crop sequence are developed by agronomist (i.e.) what type of crop, cropping pattern, cropping sequence, etc. (Rice - Rice - Pulse)
- Agronomists are also develops the method of harvesting, time for harvesting, etc. (Appropriate time of harvest essential to prevent yield loss)
- Agronomist is responsible for every decision made in the farm management. (What type of crop to be produced? How much area to be allotted for each crop? How and when to market? How and When to take other management activities?) All the decisions should be taken at appropriate time to efficiently use resources available)

Agro-climatic zones

An agro-climatic zone is a land unit uniform in respect of climate and length of growing period (LGP) which is climatically suitable for a certain range of crops and cultivars (FAO, 1983).

Classification by Planning Commission

Planning Commission of India (1989) made an attempt to delineate the country into different agro climatic regions based on homogeneity in rainfall, temperature, topography, cropping and farming systems and water resources. India is divided into 15 agro-climatic regions.

1. Western Himalayan zone

This zone consists of three distinct sub-zones of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh hills. The region consists of skeletal soils of cold region, podsolic mountain

meadow soils and hilly brown soils. Lands of the region have steep slopes in undulating terrain. Soils are generally silty loams and these are prone to erosion hazards.

2. Eastern Himalayan zone

Sikkim and Darjeeling hills, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Tripura, Mizoram, Assam and Jalpaiguri and Coochibihar districts of West Bengal fall under this region, with high rainfall and high forest cover. Shifting cultivation is practiced in nearly one-third of the cultivated area and this has caused denudation and degradation of soils with the resultant heavy runoff, massive soil erosion and floods in lower reaches and basins.

3. Lower Gangetic Plains zone

This zone consists of West Bengal-lower Gangetic plain region. The soils are mostly alluvial and are prone to floods.

4. Middle Gangetic Plains zone

This zone consists of 12 districts of eastern Uttar Pradesh and 27 districts of Bihar plains. This zone has a geographical area of 16 million hectares and rainfall is high. About 39% of gross cropped area is irrigated and the cropping intensity is 142%.

5. Upper Gangetic Plains zone

This zone consists of 32 districts of Uttar Pradesh. Irrigation is through canals and tube wells. A good potential for exploitation of ground water exists.

6. Trans-Gangetic Plains zone

This zone consists of Punjab, Haryana, Union territories of Delhi and Chandigarh and Sriganganagar district of Rajasthan. The major characteristics of this area are: highest net sown area, highest irrigated area, high cropping intensity and high groundwater utilization.

7. Eastern Plateau and Hills zone

This zone consists of eastern part of Madhya Pradesh, southern part of West Bengal and most of inland Orissa. The soils are shallow and medium in depth and the topography is undulating with a slope of 1-10%. Irrigation is through tanks and tube wells.

8. Central Plateau and Hills zone

This zone comprises of 46 district of Madhya Pradesh, part of Uttar Pradesh and Rajasthan. The topography is highly variable nearly 1/3rd of the land is not available for cultivation. Irrigation and cropping intensity are low. 75% of the area is rainfed grown with low value cereal crops. There is an intensive need for alternate high value crops including horticultural crops.

9. Western Plateau and Hills zone

This zone comprises the major part of Maharastra, parts of Madhya Pradesh and one district of Rajasthan. The average rainfall of the zone is 904 mm. The net sown area is 65% and forests occupy 11%. The irrigated area is only 12.4% with canals being the main source.

10. Southern Plateau and Hills zone

This zone comprises 35 districts of Andhra Pradesh, Karnataka and Tamil Nadu which are typically semi-arid zones. Dryland farming is adopted in 81% of the area and the cropping intensity is 111 percent.

11. East Coast Plains and Hills zone

This zone comprises of east coast of Tamil Nadu, Andhra Pradesh and Orissa. Soils are mainly alluvial and coastal sands. Irrigation is through canals and tanks.

12. West Coast Plains and Ghats zone

This zone comprises west coast of Tamil Nadu, Kerala, Karnataka, Maharastra and Goa with a variety of crop patterns, rainfall and soil types.

13. Gujarat Plains and Hills zone

This zone consists of 19 districts of Gujarat. This zone is arid with low rainfall in most parts and only 32.5% of the area is irrigated largely through wells and tube wells.

14. Western Dry zone

This zone comprises nine districts of Rajasthan and is characterized by hot sandy desert, erratic rainfall, high evaporation, scanty vegetation. The ground water is deep and often brackish. Famine and drought are common features of the region.

15. Islands zone

This zone covers the island territories of Andaman and Nicobar and Lakshadeep which are typically equatorial with rainfall of 3000 mm spread over eight to nine months. It is largely a forest zone with undulated lands. 1	Western Himalayan Region	J&K, HP, UP, Utranchal
2	Eastern Himalayan Region	Assam Sikkim, West Bengal & North-Eastern states
3	Lower Gangetic Plains Region	West Bengal
4	Middle Gangetic Plains Region	UP, Bihar
5	Upper Gangetic Plains Region	UP
6	Trans-Gangetic Plains Region	Punjab, Haryana, Delhi & Rajasthan
7	Eastern Plateau and Hills Region	Maharastra, UP, Orissa & West Bengal
8	Central Plateau and Hills Region	MP, Rajasthan, UP
9	Western Plateau and Hills Region	Maharastra, MP & Rajasthan
10	Southern Plateau and Hills Region	AP, Karnataka, Tamil Nadu
11	East Coast Plains and Hills Region	Orissa, AP, TN,& Pondichery
12	West Coast Plains and Ghat Region	TN, Kerala, Goa, Karnataka, Maharastra

Crops and major soils - Classification – Economic and agricultural importance in India and Tamil Nadu

CROPS

In general, crop is an organism grown and / or harvested for obtaining yield. Agronomically, crop is a plant cultivated for economic purpose.

Classification of crops

Classification is done to generalize similar crop plants as a class for better understanding of them.

Classification types used in crops

1. Based on ontogeny (Life cycle)
2. Based on economic use (Agronomic)
3. Based on Botany (Scientific)
4. Based on seasons
5. Based on climate

1. Based on Ontogeny (Life cycle)

a) Annual crops:

Crop plants that complete life cycle within a season or year. They produce seed and die within the season. Ex. Wheat, rice, maize, mustard etc.

b) Biennial crops:

Plants that have life span of two consecutive seasons or years. First years/ season, these plants have purely vegetative growth usually confined to rosette of leaves. The tap root is often fleshy and serves as a food storage organ. During the second year / season, they produce flower stocks from the crown and after producing seeds the plants die. Ex. Sugar beet, beet root, etc.

c) Perennial crops:

They live for three or more years. They may be seed bearing or non-seed bearing. Ex. Napier fodder grass, coconut, etc.

2. Based economic use (Agronomic)

a) Cereals: Cereal derived from word ‘Ceres’ which denotes as ‘Goddess’ who was believed as the giver of grains by Romans. Cereals are the cultivated grasses grown for their edible starchy grains. Larger grains used as staple food – Rice, wheat, maize, barley, oats etc.

Cereal grain contains 60 to 70% of starch and is excellent energy rich foods for humans. In almost every country and region, cereals provide the staple food. In the world as a whole, only 5% of starchy staple food comes from root crops (mainly cassava, potato, and yams, depending on climate), whereas the rest is from cereal. Cereals are an excellent source of fat soluble vitamin E, which is an essential antioxidant. Whole cereal grains contain 20 to 30% of the daily requirements of the minerals such as selenium, calcium, zinc and copper.

b) Millets:

Millets are small grained cereals, staple food in drier regions of the developing countries are called ‘millets’. They are also annual grasses of the group cereals. But’ they are grown in lesser area or less important area whose productivity and economics are also less important. These are also staple food for people of poor countries. In India, pearl millet is a staple food in Rajasthan.

Millets are broadly classified in to two, 1) Major millets and 2) Minor millets.

Major millets

1. Sorghum /*Jowar*/*Cholam* - *Sorghum bicolor*
2. Pearl millet /*Bajra*/*Cumbu* - *Pennisetum glaucum*
3. Finger millet or *Ragi* - *Eleusine coracona*

Minor millets

1. Foxtail millet / *Thenai* - *Setaria italica*
2. Little millet / *Samai* - *Panicum miliare*2

3. Common millet / *Panivaraugu* - *Panicum miliaceum*
4. Barnyard millet / *Kudiraivali* - *Echinchloa colona* var *frumentaceae*
5. Kodo millet / *Varagu* - *Paspalum scrobiculatum*

c) Pulses:

Seeds of leguminous plants used as food (*Dhal)* rich in protein. Pod containing grain is the economic portion. Pulses are preferred for protein rich value & also economic important in cropping system. The wastes or stalk is called the 'haulm' or 'stover'. Haulm is used as green manure and has high value cattle feed. Green pods used as vegetables, e.g. cowpea, lablab. Seed coat of pulses are nutritious cattle feed.

1. Red gram - *Cajanus cajan*
2. Black gram - *Vigna mungo*
3. Green gram - *V. radiata*
4. Cowpea - *V. unguiculata*
5. Bengalgram - *Cicer arietinum*
6. Horsegram - *Macrotyloma uniflorum*
7. Lentil - *Lens esculentus*
8. Soybean - *Glycine max*
9. Peas or gardenpea - *Pisum sativum*
10. Garden bean - *Lablab purpureus*
11. *Lathyrus/Kesari* - *Lathyrus sativus*

d) Oil seeds: Those crops which are rich in fatty acid are cultivated for the production of vegetable oil. They are used either for edible or industrial or medicinal purposes.

1. Groundnut or peanut - *Arachis hypogeae*
2. Sesame or gingelly - *Sesamum indicum*
3. Sunflower - *Helianthus annuus*
4. Castor - *Ricinus communis*
5. Linseed or flax - *Linum usitatissimum*
6. Niger - *Guizotia abyssinia*
7. Safflower - *Carthamus tinctorius*
8. Rapeseed & Mustard

Brown or Indian Mustard - *Brassica juncea*

9. Sarson - *Brassica sp.*

Groundnut:

Pod is economic portion in groundnut and contains 50% of oil content. Oil is edible or cooking oil and haulm is a used as cattle feed and also has manure value. The shell has fuel value; it is used for soil amendment. It is a bed material in the poultry forms. Oil cake is used as cattle feed and has manural value. Oil is used for production of *Vanaspathi* and soap making.

Sesame:

Sesame oil is cooking oil and economic parts are generally seeds (in the pod). Gingelly cake is used as a cattle feed, whereas capsule and stalk are used for composting / burning purpose.

Castor:

Seed (kernal) of castor contains oil and used as medicinal and industrial oil. Mainly aviation industries use this for lubrication purpose. Castor cake is concentrated organic manure. The shell and stalk is used for fuel purpose.

Mustard:

Mustard oil is edible oil and seeds are the economic portion. Oil cake is a good cattle feed.

Safflower and sunflower:3

Oil is used for cooking purpose. Both of these oils contain more of unsaturated fatty acids and used for heart patients. Cake is used as cattle feed and also organic material and decorticated manure.

Niger:

Seed is the economic portion and used in soap making, paint, varnish & light lubricant. Crop is generally an industrial crop.

Linseed:

Oil extracted from seeds is used in preparation of paints and varnishes.

e. Sugar crops

Crops cultivated for sugar. Juice is extracted from stem of sugarcane used for jaggery or sugar. Number of by products like molasses, bagasse, pressmud etc. is obtained from sugar industry. Molasses used for alcohol and yeast formation and bagasse for paper making and fuel. Pressmud used for soil amendment; whereas, trash (green leaf + dry foliage) is used for cattle feed.

Sugar beet is another sugar crop where tubers are mainly used for extraction of sugar. Tubers and tops are used as a fodder for cattle feed.

1. Sugarcane - *Saccharum officinarum*
2. Sugar beet - *Beta vulgaris*

f) Fibre crops:

Plants are grown for obtaining fibre. Different kinds of fibre are, i) seed fibre – cotton; ii) Stem/ bast fibre – Jute, mesta; iii) leaf fibre – *Agave*, pineapple.

Cotton:

Important fibre crop of the world, used for garment purpose. Seed for cattle feed and oil is edible purpose. Epidermal hairs of seed coats is the economic portion. Lint (*Kapas*-seed) has industrial value (fibre) and stalk is of fuel nature.

Jute, *Sunnhemp*, mesta:

The fibre obtained from stems is used for gunny bags, ropes. Stem itself is used as fuel.

Sunnhemp is used for both stem fibre and green manure crop.

g) Fodder / Forage: It refers to vegetative matter, fresh or preserved, utilized as feed for animals. It includes hay, silage, pasturage and fodder.

Ex. 1. Grasses - *Bajra napier* grass, guinea grass, fodder sorghum, fodder maize.

2. Legumes - Lucerne, *Desmanthus*, etc.

h) Spices and condiments: Crop plants or their products used for flavour, taste and add colour to the fresh or preserved food. Ex.– Ginger, garlic, fenugreek, cumin, turmeric, chillies, onion, coriander, anise and asafetida.

i) Medicinal plants: Crops used for preparation of medicines. Ex. Tobacco, mint. etc.

j) Beverages: Products of crops used for preparation of mild, agreeable and simulating drinking. Ex. Tea, coffee, cocoa (Plantation crops).

3. Scientific or botanical classification

Botanical or scientific names of plants which consist of genus and species and are universally accepted. Carolus Linnaeus, a Swedish botanist, was responsible for the binomial system of classification.

Group	**Grass (Wheat)**	**Legume (Alfalfa**
Kingdom	Plant	Plant
Division	Spermatophyta	Spermatophyta
Sub-division	Angiospermae	Angiospermae
Class	Monocotyledonae	Dicotyledonae
Order	Graminales	Rosales
Family	Gramineae	Leguminosae

Factors affecting crop production – climatic – edaphic - biotic- physiographic and socio economic factors

EXTERNAL FACTORS (Environmental)

A. Climatic
B. Edaphic
C. Biotic
D. Physiographic

E. Socio-economic

INTERNAL FACTORS
(Genetic or heredity)
CROP GROWTH

I. Internal factors

Genetic factors

The increase in crop yields and other desirable characters are related to Genetic make up of plants.

- High yielding ability
- Early maturity
- Resistance to lodging
- Drought flood and salinity tolerance
- Tolerance to insect pests and diseases
- Chemical composition of grains (oil content, protein content)
- Quality of grains (fineness, coarseness)
- Quality of straw (sweetness, juiciness)

The above characters are less influenced by environmental factors since they are governed by genetic make-up of crop.

2. External factors

A. Climatic
B. Edaphic
C. Biotic
D. Phsiographic
E. Socio-economic

A. CLIMATIC FACTORS

Nearly 50 % of yield is attributed to the influence of climatic factors.The following are the atmospheric weather variables which influences the crop production.

1. Precipitation
2. Temperature
3. Atmospheric humidity
4. Solar radiation
5. Wind velocity
6. Atmospheric gases

1. Precipitation

- Precipitation includes all water which falls from atmosphere such as rainfall, snow, hail, fog and dew.
- Rainfall one of the most important factor influences the vegetation of a place.
- Total precipitation in amount and distribution greatly affects the choice of a cultivated species in a place.

- In heavy and evenly distributed rainfall areas, crops like rice in plains and tea, coffee and rubber in Western Ghats are grown.
- Low and uneven distribution of rainfall is common in dryland farming where drought resistance crops like pearl millet, sorghum and minor millets are grown.
- In desert areas grasses and shrubs are common where hot desert climate exists
- Though the rainfall has major influence on yield of crops, yields are not always directly proportional to the amount of Precipitation as excess above optimum reduces the yields
- Distribution of rainfall is more important than total rainfall to have longer growing period especially in drylands

2. Temperature

- Temperature is a measure of intensity of heat energy. The range of temperature for maximum growth of most of the agricultural plants is between 15 and 40ºC.
- The temperature of a place is largely determined by its distance from the equator (latitude) and altitude.
- It influences distribution of crop plants and vegetation.
- Germination, growth and development of crops are highly influenced by temperature.
- Affects leaf production, expansion and flowering.
- Physical and chemical processes within the plants are governed by air temperature.
- Diffusion rates of gases and liquids changes with temperature.
- Solubility of different substances in plant is dependent on temperature.
- The minimum, maximum (above which crop growth ceases) and optimum temperature of individual's plant is called as cardinal temperature.

Crops	Minimum temperature ºC	Optimum temperature ºC	Maximum temperature ºC
Rice	10	32	36-38
wheat	4.5	20	30-32
Maize	8-10	20	40-43
Sorghum	12-13	25	40
Tobacco	12-14	29	35

1

Tillage – Definition – objectives – types of tillage - modern concepts of tillage – main field preparation

Tillage

Tillage operations in various forms have been practiced from the very inception of growing plants. Primitive man used tools to disturb the soils for placing the seeds. The word tillage is derived from 'Anglo-Saxon' words *Tilian* and *Teolian*, meaning 'to plough and prepare soil for seed to sow, to cultivate and to raise crops'. **Jethrotull,** who is considered as father of tillage suggested that thorough ploughing is necessary so as to make the soil into fine particles.

Tillage is the mechanical manipulation of soil with tools and implements for obtaining conditions ideal for seed germination, seedling establishment and growth of crops.

Tilth is the physical condition of soil obtained out of tillage (or) it is the result of tillage. The tilth may be a coarse tilth, fine tilth or moderate tilth.

Objectives of tillage

The main objectives of tillage are,

- To prepare a good seed bed which helps the germination of seeds.

- To create conditions in the soil suited for better growth of crops.
- To control the weeds effectively.
- To make the soil capable for absorbing more rain water.
- To mix up the manure and fertilizers uniformly in the soil.
- To aerate the soil.
- To provide adequate seed-soil contact to permit water flow to seed and seedling roots.
- To remove the hard pan and to increase the soil depth.

To achieve these objectives, the soil is disturbed / opened up and turned over.

Types of tillage: Tillage operations may be grouped into

1. On season tillage 2. Off-season tillage

1. On-season tillage

Tillage operations that are done for raising crops in the same season or at the onset of the crop season are known as on-season tillage. They may be preparatory cultivation and after cultivation.

A. Preparatory tillage: This refers to tillage operations that are done to prepare the field for raising crops. It consists of deep opening and loosening of the soil to bring about a desirable tilth as well as to incorporate or uproot weeds and crop stubble when the soil is in a workable condition.

Types of preparatory tillage

a. Primary tillage
b. Secondary tillage

a. Primary tillage: The tillage operation that is done after the harvest of crop to bring the land under cultivation is known as primary tillage or ploughing. Ploughing is the opening of compact soil with the help of different ploughs. Country plough, mould board plough, bose plough, tractor and power tiller drawn implements are used for primary tillage.

b. Secondary tillage: The tillage operations that are performed on the soil after primary tillage to bring a good soil tilth are known as secondary tillage. Secondary tillage consists of lighter or finer operation which is done to clean the soil, break the clods and incorporate the manure and fertilizers. Harrowing and planking is done to serve those purposes.

Planking is done to crush the hard clods, level the soil surface and to compact the soil lightly. Harrows, cultivators, *Guntakas* and spade are used for secondary tillage.

c. Layout of seed bed:This is also one of the components of preparatory tillage. Leveling board, buck scrapers etc. are used for leveling and markers are used for layout of seedbed.2

B. After cultivation (Inter tillage): The tillage operations that are carried out in the standing crop after the sowing or planting and prior to the harvesting of the crop plants are called after tillage. This is also called as inter cultivation or post seeding/ planting cultivation. It includes harrowing, hoeing, weeding, earthing up, drilling or side dressing of fertilizers etc. Spade, hoe, weeders etc. are used for inter cultivation.

2. Off-season tillage: Tillage operations done for conditioning the soil suitably for the forthcoming main season crop are called off-season tillage. Off season tillage may be, post harvest tillage, summer tillage, winter tillage and fallow tillage.

Special purpose tillage: Tillage operations intended to serve special purposes are said to be special purpose tillage. They are,

a. Sub-soiling: To break the hard pan beneath the plough layer, special tillage operation (chiseling) is performed to reduce compaction. Sub-soiling is essential and once in four to five years where heavy machineries are used for field operations, seeding, harvesting and transporting. Advantages of sub-soiling are, greater volume of soil may be obtained for cultivation of crops, excess water may percolate downward to recharge the permanent water table, reduce runoff and soil erosion and roots of crop plants can penetrate deeper to extract moisture from the water table.

b. Clean tillage: It refers to working of the soil of the entire field in such a way no living plant is left undisturbed. It is practiced to control weeds, soil borne pathogen and pests.

c. Blind tillage: It refers to tillage done after seeding or planting the crop (in a sterile soil) either at the pre-emergence stage of the crop plants or while they are in the early stages of growth so that crop plants (sugarcane, potato etc.) do not get damaged, but, extra plants and broad leaved weeds are uprooted.

d. Dry tillage: Dry tillage is practiced for crops that are sown or planted in dry land condition having sufficient moisture for germination of seeds. This is suitable for crops like broadcasted rice, jute, wheat, oilseed crops, pulses, potato and vegetable crops. Dry tillage is done in a soil having sufficient moisture (21-23%). The soil becomes more porous and soft due to dry tillage. Besides, the water holding capacity of the soil and aeration are increased. These conditions are more favourable for soil micro-organisms.

e. Wet tillage or puddling: The tillage operation that is done in a land with standing water is called wet tillage or puddling. Puddling operation consists of ploughing repeatedly in standing water until the soil becomes soft and muddy. Puddling creates an impervious layer below the surface to reduce deep percolation losses of water and to provide soft seed bed for planting rice. Puddling is done in both the directions for the incorporation of green manures and weeds. Wet tillage destroys the soil structure and the soil particles that are separated during puddling settle later. Wet tillage is the only means of land preparation for transplanting semi-aquatic crop plant such as rice. Planking after wet tillage makes the soil level and compact. Puddling hastens transplanting operation as well as establishment of seedlings. Wet land ploughs or worn out dry land ploughs are normally used for wet tillage.

Depth of ploughing

The desirable depth of ploughing is 12 to 20 cm for field crops. The ploughing depth varies with effective root zone of the crop. The depth of ploughing is 10-20 cm for shallow rooted crops and 15-30 cm for deep rooted crops.

Number of ploughing

Number of ploughing depends on soil conditions, time available for cultivation between two crops and type of cropping systems. Zero tillage is practiced in rice fallow pulses. Minimum number of ploughing is taken up at optimum moisture level to bring favourable tilth depending on need of the crop.3

Time of ploughing

The optimum soil moisture content for tillage is 60% of field capacity.

Modern concepts in tillage:

Conventional tillage involves primary tillage to break open and turn the soil followed by secondary tillage to obtain seed bed for sowing or planting. With the introduction of herbicides in intensive farming systems, the concept of tillage has been changed. Continuous use of heavy ploughs create hard pan in the subsoil, results in poor infiltration. It is more susceptible to run-off and erosion. It is capital intensive and increase soil degradation. To avoid these ill effects, modern concepts on tillage is in rule.

1. Minimum tillage: It aims at reducing tillage operations to the minimum necessity for ensuring a good seed bed. The advantages of minimum tillage over conventional tillage are,

- The cost and time for field preparation is reduced by reducing the number of field operations.
- Soil compaction is comparatively less.
- Soil structure is not destroyed.
- Water loss through runoff and erosion is minimum.
- Water storage in the plough layer is increased.

Tillage can be reduced in 2 ways

1. By omitting operations which do not give much benefit when compared to the cost.
2. By combining agricultural operations like seeding and fertilizer application.

The minimum tillage systems can be grouped into the following categories,

1. Row zone tillage

Primary tillage is done with mould board plough in the entire area of the field; secondary tillage operations like discing and harrowing are reduced and done only in row zone.

2. Plough plant tillage

After the primary tillage, a special planter is used for sowing. In one run over the field, the row zone is pulverized and seeds are sown by the planter

3. Wheel track tillage

Primary ploughing is done as usual. Tractor is used for sowing; the wheels of the tractor pulverize the row zone in which planting is done.

In all these systems, primary tillage is as usual. However, secondary tillage is replaced by direct sowing in which sown seed is covered in the row zone with the equipment used for sowing.

2. Zero tillage (No tillage): In this, new crop is planted in the residues of the previous crop without any prior soil tillage or seed bed preparation and it is possible when all the weeds are controlled by the use of herbicides. Zero tillage is applicable for soils with a coarse textured surface horizon, good internal drainage, high biological activity of soil fauna, favourable initial soil structure and an adequate quantity of crop residue as mulch. These conditions are generally found in *Alfisols*, *Oxisols* and *Ultisols* in the humid and sub-humid tropics.

Till planting

Till planting is one method of practicing zero tillage. A wide sweep and trash bar clears a strip over the previous crop row and planter opens a narrow strip into which seeds are planted and covered. Here, herbicide functions are extended. Before sowing, the vegetation present has to be destroyed for which broad spectrum non selective herbicides like glyposate, paraquat and diquat are used.

Advantages

- Zero tilled soils are homogenous in structure with more number of earthworms.

• Organic matter content increases due to less mineralization.

• Surface run-off is reduced due to presence of mulch.

Disadvantages
- Higher amount of nitrogen has to be applied for mineralization of organic matter in zero tillage.
- Perennial weeds may be a problem.
- High number of volunteer plants and buildup of pests.

3. Stubble mulch tillage or stubble mulch farming

Soil is protected at all times either by growing a crop or by leaving the crop residues on the surface during fallow periods. Sweeps or blades are generally used to cut the soil up to 12 to 15 cm depth in the first operation after harvest and depth of cut is reduced during subsequent operations. When large amount of residues are present, a disc type implement is used for the first operation to incorporate some of the residues into the soil. This hastens the decomposition but still keeps enough residues on top soil.

Two methods for sowing crops in stubble mulch tillage are,

1. Similar to zero tillage, a wide sweep and trash bars are used to clear a strip and a narrow planter shoe opens a narrow furrow into which seeds are placed.
2. A narrow chisel of 5-10 cm width is worked through the soil at a depth of 15-30 cm leaving all plant residues on the surface. The chisel shatters the tillage pans and surface crusts. Planting is done with special planters.

Disadvantages of stubble mulch farming
- The residues left on the surface interfere with seed bed preparation and sowing operations.
- The traditional tillage and sowing implements or equipments are not suitable under these conditions.

4. Conservation tillage: The major objective is to conserve soil and soil moisture. It is a system of tillage in which organic residues are not inverted into the soil such that they remain on surface as protective cover against erosion and evaporation losses of soil moisture. If stubble forms the protective cover on the surface, it is usually referred to as stubble mulch tillage. The residues left on soil surface interfere with seed bed preparation and sowing operations. It is a year round system of managing plant residue with implements that undercut residues, losses the soil and kills the weeds.

Advantages
- Energy conservation through reduced tillage operations.
- Improve the soil physical properties.
- Reduce the water runoff from fields.

Main field preparation:

Tillage operations are generally classified in to two, preparatory cultivation and after cultivation. The preparatory cultivation or tillage is operations that are done before the cultivation. This preparatory cultivation is generally called as main field preparation. The main field preparation involves three processes, viz., primary tillage, secondary tillage and lay-out for sowing. Some of the important primary tillage implements are country plough, mould board plough, disc plough, chisel plough etc. Cultivators and harrows are generally used for secondary tillage purpose. However, in

practical means, the first two (primary and secondary tillages) may not have any key difference, since; both operations are mainly carried out with same implement. Country plough and cultivators are used for both the purposes. After thorough ploughing, the field modified in to suitable way for planting such as ridges and furrows or beds and channels or pit according to the need of the crops. Such field modifications are mandatory for better crop production.

1

Seeds - Seed rate - Sowing methods - Germination - Crop stand establishment - Planting geometry

SEEDS

Plant propagation is made in two ways, Sexual (by seeds) and asexual (by vegetative means). Biologically, seed is a ripe, fertilized ovule and a unit of reproduction of flowering plants.

SEED RATE

The required number of plants/unit area is decided by calculating the seed rate. The seed rate depends on spacing or plant population, test weight, germination percentage. The formula is as follows.

$$\text{Seed rate (kg/ha)} = \frac{\text{Plant population (per ha) x No. of seeds/hill x Test weight (g) x 100}}{\text{1000 x 1000 x Germination percentage (\%)}}$$

SOWING METHODS

1. Broadcasting
2. Dibbling
3. Sowing behind the country plough (manual and mechanical drilling)
4. Seed drilling
5. Nursery transplanting

1. Broadcasting

Broadcasting is otherwise called as random sowing. Literally means ‘scattering the seeds’. Broadcasting is done for many crops. Broadcasting is mostly followed for small sized to medium sized crops. This is the largest method of sowing followed in India, since; it is the easiest and cheapest and requires minimum labours. To have optimum plant population in unit area certain rules should be followed.

- Only a skilled person should broadcast the seeds for uniform scattering.
- The ploughed field should be in a perfect condition to trigger germination.

The seeds are broadcasted in a narrow strip and the sowing is completed strip by strip. To ensure a good and uniform population, it is better to broadcast on either direction. This is called criss-cross sowing. If the seed is too small, it is mixed with sand to make a bulky one and for easy handling. Ex. Seasame seeds are mixed with sand at 1:15 or 1:10 ratio and sown.

In certain cases the person sowing will be beating the seeds against the basket for uniform scattering. Ex. Sorghum, pearl millet.

After broadcasting, the seeds are covered gently either using a country plough with a very shallow ploughing or some wooden planks (boards / levelers) are used to cover the surface. In some cases, tree twigs or shrub branches are used. If the seeds are large, levelers collect the seeds and leave in the other side. Comb harrow is the best used one.

Disadvantages

- All the seeds broadcasted do not have contact with the soil. 100% germination is not possible.
- Enhanced seed rate is required.
- Seeds cannot be placed in desired depth. Desired depth ensures perfect anchorage. Lodging (falling down) is common in broadcasting.

2. Dibbling

This is actually line sowing. Inserting a seed through a hole at a desired depth and covering the hole. Dibbling is practiced on plain surface and ridges and furrows or beds and channels. This type of sowing is practiced only under suitable soil condition. Rice fallow cotton is dibbled on a 2 from top or 1/3at bottom of the ridge. Before sowing, furrows are opened and fertilizers are applied above which seeds are sown. The seeds do not have contact with the fertilizers. This is done for wider spaced crops and medium to large sized seeds. Ex. Sorghum, maize, sunflower, cotton are dibbled on ridges and furrows. Both beds and channels; and ridges and furrows come under line sowing. While earthing up, the plant occupies middle of the ridge. Earthing up is essential for proper anchorage of the root system.

plain surface. The seedsare dibbled at 2/3rd from top or 1/3rd at bottomof the ridge. Before sowing,furrows are opened and fertilizers are applied above which seeds are sown. The seeds do not havecontact with the fertilizers. This is done for wider spaced crops and medium to large sized seeds.Ex.Sorghum, maize, sunflower, cotton are dibbled on ridges and furrows. Both bedsand channels;and ridges and furrows come under line sowing. While earthing up,theplant occupies middle ofthe ridge. Earthing up isessential for proper anchorage of the root system.

Advantages ofline sowingare,(i) uniform population, (ii) betterger mination, (iii) reduced seed rate.**Sl.No.**	**Dibbling (Line sowing)**	**Broadcasting (Random sowing)**
1.	Costlier	Cheaper
2.	Takes considerable time	Quickest and time saving
3.	Fixed seed rate	Higher seedrate
4.	Mechanization is possible, e.g. weeding, harvesting	Not possible
5.	Uniform utilization of resources (land, water, light,nutrient, etc.)	Resource utilizationis un-uniform

Role of manures and fertilizers in crop production – agronomic interventions for enhancing FUE - Inter cultivation - Thinning - Gap filling and other intercultural operations

MANURES

Manures are plant and animal wastes that are used as source of plant nutrients. They release nutrients after their decomposition. Manures can be grouped into bulky organic manures and concentrated organic manures.

a. Bulky organic manures - Farm Yard Manure (FYM), compost from organic waste, night soil, sludge, sewage, green manures.
b. Concentrated organic manures - oilcakes (edible, non-edible), blood meal, fishmeal and bone meal.

FERTILIZERS

Fertilizers are industrially manufactured chemical containing plant nutrients. Nutrient content is higher in fertilizers than organic manures and nutrients are released almost immediately. The fertilizers has three groups;

Straight fertilizers – supplies single nutrient Ex: Urea, Muriate of Potash

Complex fertilizers - supplies two or more nutrient Ex: 17:17:17 NPK complex

Mixed fertilizers- supplies two or more nutrient Ex: Groundnut mixture

ROLE OF MANURES AND FERTILIZERS

1. Organic manures bind the sandy soil and improve its water holding capacity.
2. Organic manures open the clayey soil and help in aeration for better root growth.
3. Organic manures add plant nutrients in small percentage and also add micronutrients, which are essential for plant growth.
4. Manures increases the microbial activity which helps in releasing plant nutrients to available form.
5. Organic manures should be incorporated before the sowing or planting because of slow release of nutrients.
6. Fertilizers play an important role in crop production as they supply large quantities of essential nutrient to crops
7. Fertilizers are manufactured in forms that are readily utilized by plants directly or after rapid transformation.
8. Fertilizers dose can be adjusted to suit the requirement as determined by soil testing.
9. Balanced application of nutrient based on crop requirement is possible by appropriate mixing of fertilizers.
10. Fertilizers applied as straight fertilizers (providing single nutrient) or complex and mixed fertilizers (supplies two or more nutrients) based on crop requirement.

AGRONOMIC INTERVENTIONS FOR ENHANCING FUE

The following are the agronomic measures to improve the Fertilizer use efficiency (FUE).

1. Using best fertilizer source
2. Using adequate rate & diagnostic techniques
3. Usage of balanced fertilization
4. Integrated nutrient management
5. Utilization of residual nutrients

1. Using best fertilizer source:

Identification of best source of fertilizer is pre-requisite for better crop production. Source of fertilizer depends on crop and variety, climatic and soil condition, availability of fertilizer, etc.

- Nitrogen: Ammoniacal or Nitrate
- Phosphorus: Water soluble or Citrate soluble
- Potassium: Muriate of potash
- Sulphur: Sulphate or Elemental S
- Multinutrient fertilizers: MAP, DAP, SSP, Nitrophosphates
- Multi-nutrient mixtures: Several combinations of NPK
- Fortified fertilizers: Neem-coated urea, Zincated urea, Boronated SSP, NPKS mix.

2. Using adequate rate & diagnostic techniques:

The fertilizer recommendation must be in adequate quantity so as to meet the demand of crop at any point of growth. The fertilizer supply is made by diagnosing its requirement by any of the following method.

- State recommended generalized fertilizer dose or blanket recommendation
- Soil-test based fertilizer recommendations
- Soil-test crop response based recommendation
- Plant analysis for diagnosing nutrient deficiencies
- Chlorophyll meter and Leaf colour charts, etc.

3. Balanced fertilization

Balanced fertilization includes adequate supply of all essential nutrients, proper method of application, right time of application and nutrient interrelationships.

a. Adequate supply of all essential nutrients: Due to more concentration and application on primary nutrients (NPK), soils developed deficiency symptoms for secondary and micro-nutrients. Hence, ignored elements must be added with the NPK (may be in minor quantity) to get higher yields in crops. Experimental results shown that about 20-25 kg of micro-nutrient application or two foliar sprays increases the yield of crops up to 20%.

b. Proper method: N and K can be applied as broadcasting and band placement. Water soluble P fertilizers are preferred to apply as band placement in neutral & alkaline soils. Citrate soluble P fertilizers are applied as broadcast method in acidic soils. Sulphate forms of S fertilizers are applied as broadcasting or band placement, whereas, elemental S and pyrite are applied as broadcasting method. Micronutrients are applied in minor quantity as foliar sprays and water soluble fertilizers are applied in fertigation.

c. Right time: (according to physiology of crop)

- Upland crops - 2 splits (seeding, 3-5 weeks after first dose)
- Flooded rice - 3 splits (Transplanting, 3 and 6 weeks after first dose)

d. Nutrient interrelationships:

Antagonistic nature of fertilizers is to be considered while applying into the soil. Some of the fertilizer application in excess, cause loss of yield and quality of crops. Ex. Application of excessive 120 kg P ha^{-1} created an imbalance and reduced the seed and oil yields in soybean compared to 80 kg P ha^{-1}.

4. Integrated nutrient management

Organic manures, crop residues, green manures, bio-fertilizers etc. are to be blended in right manner along with inorganic fertilizers to meet the crop demand. All the possible and available organic sources are to be utilized efficiently to reduce the usage of inorganic fertilizers.

5. Utilization of residual nutrients

Some of the strategies to utilize the crop residues in efficient manner are,

- Knowledge on climatic conditions & carry-over effects of residues.
- Blending rightly on cereal-legume rotations
- Mixing shallow-deep rooted crop rotations

INTER CULTIVATION

Cultivation practices taken up after sowing of crop is called inter-cultivation. It is otherwise called as after operation. There are three important after cultivation processes viz., Thinning and gap filling, weeding and hoeing and earthing up.

1. Thinning and Gap filling

The objective of thinning and gap filling process is to maintain optimum plant population. Thinning is the removal of excess plants leaving healthy seedlings. Gap filling is done to fill the gaps by sowing of seeds or transplanting of seedlings in gap where early sown seed had not germinated. It is a simultaneous process. Normally, these are practiced a week after sowing to a maximum of 15 days. In dryland agriculture, gap filling is done first. Seeds are dibbled after 7 days of sowing. Thinning is done after gap filling; in order to avoid drought. It is a management strategy to remove a portion of plant population to mitigate stress is referred to as mid season correction.

2. Weeding and Hoeing

Weeding is removal of unwanted plants. Weeding and hoeing is a simultaneous operation. Hoeing is disturbing the top soil by small hand tools and helps in aerating the soil.

3. Earthing up

It is a dislocation of soil from one side of a ridge and to be placed nearer the cropped side. It is carried out in wide spaced and deep rooted crops. It is done around 6-8 weeks after sowing / planting in sugarcane, tapioca, banana, etc.

4. Other inter cultivation practices

Harrowing

Stirring or scraping the surface soil in inter and intra row spacing of the crop using tools or implements.

Roguing

Removal of plants of a variety admixed with other variety of same crop. Ex. In IR 50 rice field, the other rice varieties are rogue. It is practiced in seed production to maintain purity.

Topping

Removal of terminal buds. It is done to stimulate auxillary growth. Practiced in cotton and tobacco.

Propping

Provision of support to the crop is called propping. Practiced in sugarcane commonly. It is done to prevent lodging of the crop. Cane stalks from adjacent rows are brought together and tied with their own trash and old leaves.

De-trashing

Removing of older leaves from the sugarcane crop.

De-suckering

Removal of axillary buds and branches which are considered non essential for crop production and which removes plant nutrients considerably are called suckers. Ex. Tobacco.

Irrigation - Time and methods - Modern techniques of irrigation - Drainage and its importance

IRRIGATION

Irrigation is defined as the artificial application of water to the soil for the purpose of crop production in supplement to rainfall and ground water contribution.

Importance of water to plants

1. Plants contain 90% water which gives turgidity and keeps them erect
2. Water is an essential part of protoplasm
3. It regulates the temperature of the plant system
4. It is essential to meet the transpiration requirements
5. It serves as a medium for dissolving the nutrients present in the soil
6. It is an important ingredient in photosynthesis

TIME OF IRRIGATION

Crops draw water from the moisture stored in the soil. When the moisture present in the soil is low, then the plant requirements are not met with. When the soil is supplied with moisture in excess the supply of air is reduced that limits the plants growth. In between, there is a range of moisture content that is called as optimum soil moisture range for plant growth.

The upper limit of the optimum soil moisture range is the field capacity (-0.01 to -0.03 Mpa) and the lower limit is just above the wilting point (-1.5 Mpa). The objective of irrigation is to store the moisture in the soil between these limits. Immediately after irrigation, all the macro and micropores will be filled with water. All the water present in macropores will drain to subsoil within 48 hours and moisture in micropores will be available to plants.

As the soil dries due to loss of water by evaporation and transpiration, the plant wilts during day time to conserve moisture and become normal at night. When the same condition continues, the plant will wilt without dieing. This condition is called as wilting coefficient. The irrigation is given whenever plants require water. This is decided by the crop and soil appearance.

IRRIGATION METHODS

1. Surface 2. Sub-surface 3. Pressurized irrigation

Criteria for selection of irrigation method

- Water supply source
- Topography
- Quantity of water to be applied
- The crop
- Method of cultivation

Surface irrigation methods

Oldest (4000 years back) and most common method. 90% of world's total irrigated area is under this method. In USA also, 66% is by surface irrigation. This method is most suitable for low to moderate infiltration rates and leveled lands and having <2-3% slope. It is labour intensive.

Surface is grouped as Border, check basin and furrow irrigations. Border is again classified in to two as straight and contour. Check basins may be of rectangular, contour or ring, furrow irrigation is classified as deep furrow and corrugated furrows. These may be again straight or contour according to direction and leveled and graded as per their elevation.

1. Border irrigation

The land is divided into number of long parallel strips called borders. These borders are separated by low ridges. The border strip has a uniform gentle slope in the direction of irrigation. Each strip is irrigated independently by turning the water in the upper end. The water spreads and flows down the strip in a sheet confined by the border ridges.

***Suitability*:** Suitable to soils having moderately low to moderately high infiltration rates. It is not used in coarse sandy soils that have very high infiltration rates and also in heavy soils having very low infiltration rate. Suitable to irrigate all close growing crops like wheat, barley, fodder crops and legumes and not suitable for rice

Advantages

a) Border ridges can be constructed with simple farm implements like bullock drawn "A" frame ridger or bund former.
b) Labour requirement in irrigation is reduced as compared to conventional check basin method.
c) Uniform distribution of water and high water application efficiencies are possible.
d) Large irrigation streams can be efficiently used.
e) Adequate surface drainage is provided if outlets are available.

IRRIGATION METHODS
Flooding
Level
Ring
Contour
SUB SURFACE
Straight
DRIP
Check basin
SPRINKLER
Deep furrow
Rectangular
Corrugated furrow
SURFACE
Basin
Border
Furrow
Contour
Graded
Level
Contour
Graded
Surface
Sub surface
Overhead
Micro sprinkler
Overhead sprinklers
Raingun
Center Pivot

2. Check basin irrigation

It is the most common surface irrigation method. Here, the field is divided into smaller unit areas so that each has a nearly level surface. Bunds or ridges are constructed around the area forming basins within which the irrigation water can be controlled. The water applied to a desired depth can be retained until it infiltrates into the soil. The size of the basin varies from 10 m^2 to 25 m^2 depending upon soil type, topography, stream size and crop.

Adaptability

- Small gentle and uniform land slopes and soils having moderate to low infiltration rates.
- Adapted to grain and fodder crops in heavy soils and suitable to permeable soils

Advantages

- Check basins are useful when leaching is required to remove salts from the soil profile.
- Rainfall can be conserved and soil erosion is reduced by retaining large part of rain
- High water application and distribution efficiency.

Limitations

- The ridges interfere with the movement of implements.
- More area occupied by ridges and field channels.
- The method impedes surface drainage
- Precise land grading and shaping are required
- Labour requirement is higher.
- Not suitable for crops which are sensitive to wet soil conditions around the stem

3. Furrow irrigation

It is used for row crops. The furrows are formed between crop rows. The dimension of furrows depend on the crop grown, equipment used and soil type. Water is applied by small running streams in furrows between the crop rows. Water infiltrates into soil and spreads laterally to wet the area between the furrows. In heavy soils, furrows can be used to dispose the excess water.

Adaptability

- Method used for wide spaced row crops including vegetables.
- Suitable for maize, sorghum, sugarcane, cotton, tobacco, groundnut, potatoes
- Suitable to most soils except sandy.

Advantages

- Water in furrows contacts only 1/2 to 1/5 of the land surface.
- Labour requirement for land preparation and irrigation is reduced.
- Compared to check basins, there is less wastage of land in field ditches

There are three types of furrow irrigation, they are, all furrow irrigation, alternate furrow irrigation and skip furrow irrigation

4. Surge irrigation

- Surge irrigation is the application of water into the furrows intermittently in a series of relatively short ON and OFF times of irrigation cycle.
- It has been found that intermittent application of water reduces the infiltration rate over surges thereby the water front advances quickly. Hence, reduced net irrigation water requirement.
- This also results in more uniform soil moisture distribution and storage in the crop root zone compared to continuous flow.
- The irrigation efficiency is in between 85 and 90%.

II. SUB-SURFACE IRRIGATION

In subsurface irrigation, water is applied beneath the ground by creating and maintaining an artificial water table at some depth, usually 30-75 cm below the ground surface. Moisture moves upwards towards the land surface through capillary action. Water is applied through underground field trenches laid 15-30 m apart. Open ditches are preferred because they are relatively cheaper and suitable to all types of soil. The irrigation water should be of good quality to prevent soil salinity.

Advantages

- Minimum water requirement for raising crops
- Minimum evaporation and deep percolation losses
- No wastage of land
- No interference to movement of farm machinery
- Cultivation operations can be carried out without concern for the irrigation period.

Disadvantages

- Requires a special combination of natural conditions.

- There is danger of water logging
- Possibility of choking of the pipes lay underground.
- High cost.

III. PRESSURIZED OR MODERN IRRIGATION SYSTEMS

a. Drip irrigation system

Or trickle irrigation is one of the latest and modern methods of irrigation. It is suitable for water scarcity and salt affected soils. Water is applied in the root zone of the crop. Standard water quality test needed for design and operation of drip irrigation system.

Drip components

- A drip irrigation system consists of a pump or overhead tank, main line, sub-mains, laterals and emitters.
- The mainline delivers water to the sub-mains and the sub-mains into the laterals.
- The emitters which are attached to the laterals distribute water for irrigation.
- The mains, sub-mains are usually made of PVC (poly vinyl chloride) pipes and and laterals of LLDPE tubes. The emitters are also made of PVC material.
- The other components include pressure regulator, filters, valves, water meter, fertilizer application devices etc.

Advantages of drip irrigation

- High water use efficiency (~95%, compared to less than 50% in surface)
- Flexibility of wetted area
- Versatile selection of emitters: type, discharge rate, position
- Economy in weed control
- Low interference with cultivation
- Day and night irrigation
- Prevention of leaf wetting
- Energy saving
- Salinity control
- Irrigation at variable topographic conditions.

Limitation of drip Irrigation

- High investment
- High level of knowledge for optimal and economical operation
- Susceptibility to mechanical damage
- Large number of emitters
- Long application time
- High level of filtration and other controls
- Maintenance.

b. Sprinkler irrigation system

This is another important modern irrigation techniques followed all over the globe. Sprinkler irrigation is application simulating rainfall overhead so overhead sprinklers. The sprinkler (overhead or pressure) irrigation system conveys water to the field through pipes (aluminium or PVC) under pressure with a system of nozzles. This system is designed to distribute the required depth of water uniformly, which is not possible in surface irrigation. Water is applied at a rate less than the infiltration rate of the soil hence the runoff from irrigation is avoided.

Types of sprinkler system

On the basis of arrangement for spraying irrigation water, they are classified as, rotating head (or) revolving sprinkler system and perforated pipe system

Based on the portability, sprinkler systems are classified as, portable system, semi permanent system, solid set system and permanent system.

Advantages of sprinkler

- Suitable for undulating topography (sloppy lands)
- Water saving (35-40%) compared to surface irrigation methods.
- Fertilizers and other chemicals can be applied through irrigation water
- Saving in fertilizers, even distribution and avoids wastage.
- Reduces erosion
- Suitable for coarse textured soils (sandy soils)
- Frost control - protect crops against frost and high temperature
- Drainage problems eliminated
- Saving in land

Limitations

- High initial cost
- Efficiency is affected by wind
- Higher evaporation losses in spraying water
- Not suitable for tall crops like sugarcane
- Not suitable for heavy clay soils
- Poor quality water can not be used (Sensitivity of crop to saline water and clogging of nozzles)

Drainage

Drainage is the artificial removal of water in excess of the quantity required for the crop. Drainage includes removal of excess water of both surface and subsurface in the root zone of crops. Irrigation and drainage go together and are not mutually exclusive. Irrigation aims at supplying optimum quantities of water throughout the crop period, whereas, drainage aims at removing excess quantity of water in a short time. Often, both may be required together to assure sustained and high level production of crops.

Role of drainage

- Draining the land provides conditions favorable for crop production.
- The greatest benefit of drainage relates to aeration. Good drainage facilitates the ready diffusion of oxygen to the root zone and escape of carbon dioxide from the root zone into the atmosphere. Several harmful gases also escape from the root zone into the atmosphere.
- The activity of aerobic organisms which influence the availability of nutrients such as nitrogen and sulphur to plants depends on soil aeration and hence, drainage improves aerobic organisms.
- Toxicity in acid soils due to excess iron and manganese is decreased by drainage (due to presence of oxygen in the root zone).
- Drainage permits roots to grow deeper and spread wider thereby increasing the volume of soil from which nutrients can be extracted.
- The removal of excess water helps in drying of the soil quickly and optimum soil temperature permits timeliness of field operations.
- The provision of a good drainage system permits the removal of excess salts in the soil or irrigation water and prevents their build up in the upper soil layers.

PLANTING GEOMETRY AND ITS EFFECT ON GROWTH AND YIELD

Methods of Sowing and Transplanting

1. Broadcasting
2. Dibbling
3. Sowi ng behind the country plough (manual and mechanical drilling)
4. Seed Drilling
5. Nursery transplanting

1) Broadcasting

Literally means scattering the seeds. Broadcasting is done for many crops. Broadcasting is mostly followed for small sized to medium sized crops. This is the largest method of sowing followed in India since it is the easiest and cheapest and requires minimum labours. To have optimum plant population in unit area certain rules should be followed.

i) Only a skilled person should broadcast the seeds for uniform scattering
ii) The ploughed field should be in a perfect condition to trigger germination

The seeds are broadcasted in a narrow strip and the sowing is completed strip by strip. To ensure a good and uniform population, it is better to broadcast on either direction. This is called criss-cross sowing. If the seed is too small, it is mixed with sand to make a bulky one and for easy handling. In certain cases the person sowing will be beating the seeds against the basket for uniform scattering. After broadcasting the seeds are covered gently either using a country plough with a very shallow ploughing or some wooden planks (boards / levelers) are used to cover the surface. In some cases tree twigs or shrub branches are used. If the seeds are large, levelers collect the seeds and leave in the other side. Comb harrow is the best used one.

Disadvantages

1) All the seeds broadcasted do not have contact with the soil. 100% germination is not possible.

2) Seed rate is not sufficient. Enhanced seed rate required
3) Seeds cannot be placed in desired depth. Desired depth ensures perfect anchorage. Lodging (falling down) is common in broadcasting

2) Dibbling

Line sowing: Inserting a seed through a hole at a desired depth and covering the hole. Dibbling on plain surface and ridges and furrows or beds and channels.This types of sowing is practiced only under suitable soil condition. Rice – fallow – cotton is dibbled on a plain surface. The seeds are dibbled at 2/3rd from top or 1/3rd at bottom. Before sowing furrows are opened and fertilizers are applied above which seeds are sown. The seeds do not have contact with the fertilizers. This is done for wider spaced crops and medium to large sized seeds, e.g., sorghum, maize, sunflower, cotton are dibbled on ridges and furrows. Both beds and channels and ridges and furrows come under line sowing. While earthing up the plant occupies middle of the ridge. Earthing up is essential for proper anchorage of the root system.

Advantages of ridges and furrows

(i) Uniform population
(ii) Better germination
(iii) Reduced seed rate.

3) Sowing behind the plough

Sowing behind the plough (line sowing) is done manually or mechanical means. Seeds are dropped in the furrows opened by the plough and the same is closed or covered when the

next furrow is opened. The seeds are sown at uniform distance. Manual method is a laborious and time consuming process. Seeds like redgram, cowpea and groundnut are sown behind the country plough. Major sown crop is ground out. Seeds are sown by mechanical means by 'Gorus' – seed drill. A seed drill has a plough share and hopper. Seeds are placed on hopper. Different types of seed drill are available, e.g., simple Goru – Guntakas.

Advantages – i) The seeds are placed at desired depth covered by iron planks, ii) except very small, very large seeds most of the seeds can be sown, e.g. maize, sorghum, millets, sunflower, etc.

Sl. No.	**Line sowing**	**Random sowing**
1.	Costlier	Cheaper
2.	Takes considerable time	Quickest and time saving
3.	Fixed seed rate	Higher seed rate
4.	Mechanization is possible, e.g. weeding, harvesting	Not possible
5.	Uniform utilization of resources (land, water, light, nutrient, etc.)	Resource utilization ununiform

Cropping pattern and cropping system - Intensive cropping- Sustainable agriculture – IFS

CROPPING PATTERN AND CROPPING SYSTEM

Traditionally, increased food production has come from putting more land under cultivation. However, in large areas of the world, especially in Asia, all the land that can be economically cultivated is already in use. In future, most of the extra food needs must come from higher production from land already being farmed. A major share of this increase is likely to come from increasing the number of crops produced per year on a given land using improved crop cultivars. Such multiple cropping offers potential not only to increase food production but also land degradation.

In India, the concept of cropping systems is as old as agriculture. Farmers preferred mixed cropping, especially under dry land conditions, to minimise the risk of total crop failure. Even in Vedas, there is a mention of first and second crops, indicating the existence of sequential cropping.

A **system** is defined as a set of components that are interrelated and interact among themselves. A **cropping system** refers to a set of crop systems, making up the cropping activities of a farm system. Cropping system comprises all components required for the production of a particular crop and the interrelationships between them and environment (TAC, CGIAR, 1978). In other words, a cropping system usually refers to a combination of crops in time and space. Combination in time occurs when crops occupy different growing period and combinations in space occur when crops are inter planted. When annual crops are considered, a cropping system usually means the combination of crops within a given year (Willey *et al.,* 1989

Cropping pattern

The yearly sequence and spatial arrangement of crops or of crops and fallow on a given area.

Cropping system

The cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, and available technology which determine their make up.

INTENSIVE CROPPING

Principles

The turn around period between one crop and another is minimised through modified land preparation. It is possible when the resources are available in plenty. Ex. Garden land cultivation. Cropping intensity is higher in intensive cropping system. Crop intensification technique includes intercropping, relay cropping, sequential cropping, ratoon cropping, etc. All such systems come under the general term multiple cropping.

Need for intensive cropping

- Cropping systems has to be evolved based on climate, soil and water availability for efficient use of available natural resources.
- The increase in population has put pressure on land to increase productivity per unit area, unit time and for unit resource used.
- This cropping system should provide enough food for the family, fodder for cattle and generate sufficient cash income for domestic and cultivation expenses.

Intensive cropping: Growing number of crops on the same piece of land during the given period of time.

Cropping intensity: Number of crops cultivated in a piece of land per annum is cropping intensity. In Punjab and Tamil Nadu, the cropping intensity is more than 100% (i.e. around 140-150%). In Rajasthan, the cropping intensity is less.

Multiple cropping: The intensification of cropping in time and space dimensions. Growing two or more crops on the same field in a year.

Forms of multiple cropping

Intercropping: Growing two or more crops simultaneously on the same field. Crop intensification is in both time and space dimensions. There is intercrop competition during all or part of crop growth.

(a) *Mixed intercropping:* Growing two or more crops simultaneously with no distinct row arrangement. Also referred to as mixed cropping. Ex: Sorghum, pearl millet and cowpea are mixed and broadcasted in rainfed conditions.

(b) *Row intercropping:* Growing two or more crops simultaneously where one or more crops are planted in rows. Often simply referred to as intercropping. Maize + greengram (1:1), Maize + blackgram (1:1), Groundnut + Rredgram (6:1)

(c) *Strip intercropping:* Growing two or more crops simultaneously in strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically. Ex. Groundnut + redgram (6:4) strip.

(d) *Relay intercropping:* Growing two or more crops simultaneously during the part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth, but, before it is ready for harvest. Often simply referred to as relay cropping. Rice-rice fallow pulse.

Advantages of intercropping

- Better use of growth resources including light, nutrients and water
- Suppression of weeds
- Yield stability; even if one crop fails due to unforeseen situations, another crop will yield and gives income
- Successful intercropping gives higher equivalent yields (yield of base crop + yield of intercrop), higher cropping intensity
- Reduced pest and disease incidences
- Improvement of soil health and agro-eco system

Sequential cropping: Growing two or more crops in sequence on the same field in a farming year. The succeeding crop is planted after the preceding crop has been harvested. Crop intensification is only in time dimension. There is no intercrop competition.

(a) *Double, triple and quadruple cropping:* Growing two, three and four crops, respectively, on the same land in a year in sequence.

Ex. Double cropping: Rice: cotton; Triple cropping: Rice: rice: pulses; Quadruple cropping: Tomato: ridge gourd: *Amaranthus* greens: baby corn

(b) *Ratoon cropping:* The cultivation of crop re-growth after harvest, although not necessarily for grain. Ex. Sugarcane: ratoon; Sorghum: ratoon (for fodder).

The various terms defined above bring out essentially two underlying principles, that of growing crops simultaneously in mixture, i.e., intercropping; and of growing individual crops in sequence, i.e., sequential cropping. The cropping system for a region or farm may comprise either or both of these two principles.

SUSTAINABLE AGRICULTURE

Definition:

A farming systems that are "capable of maintaining their productivity and usefulness to society indefinitely and must be resource-conserving, socially supportive, commercially competitive, and environmentally sound."

USDA (legal)

Sustainable agriculture means, an integrated system of plant and animal production practices having a site-specific application that will, over the long term:

- satisfy human food and fiber needs;
- enhance environmental quality and the natural resource based upon which the agricultural economy depends;
- make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls;
- sustain the economic viability of farm operations;
- enhance the quality of life for farmers and society as a whole.

Advantages

- Production cost is low
- Over all risk of the farmer is reduced
- Pollution of water is avoided
- Very little or no pesticide residue is ensured
- Ensures both short and long term profitability

Disadvantages

- Since sustainable agriculture uses least quantum of inputs, naturally the output (yield) may also be less.

Major components of sustainable agricultural system

- Soil and water conservation to prevent degradation of soil productivity
- Efficient use of limited irrigation water without leading to problems of soil salinity, alkalinity and high ground water table
- Crop rotations that mitigate weed, disease and insect problems, increase soil productivity and minimise soil erosion
- Integrated nutrient management that reduces the need for chemical fertilizers improves the soil health and minimise environmental pollution by conjunctive use of organics, in-organics and bio-fertilizers.
- 'Integrated pest management that reduces the need for agrochemicals by crop rotation, weather monitoring, use of resistant cultivar, planting time and biological pest control.
- Management system to control weed by preventive measures, tillage, timely inter cultivation and crop rotation to improve plant health.

INTEGRATED FARMING SYSTEM (IFS)

Integration of two or more appropriate combination of enterprises like crop, dairy, piggery, fishery, poultry, bee keeping etc., for each farm according to the availability of resources to sustain and satisfy the necessities of the farmer

Definition: A farming system is a collection of distinct functional units such as crop, livestock, processing, investments and marketing activities which interact because of the joint use of inputs they receive from the environment which have the common objective of satisfying the farmers' (decision makers) aims. The definition of the borders of the options depends on circumstances; often it includes not only the farm (economic enterprise) but also the household (farm – household system)"

Possible enterprises

Wetland based farming system

- Crop + Fish + Poultry/poultry/pigeon

• Crop + Fish + Mushroom

Gardenland based farming system

- Crop + Dairy + Biogas
- Crop + Dairy + Biogas + Sericulture
- Crop + Dairy + Biogas + Mushroom + Sylvi-culture

Dry land based farming system

- Crop + Goat + Agroforestry
- Crop + Goat + Agroforestry + Horticulture

Benefits of IFS

- Higher Productivity
- Profitability
- Sustainability
- Balanced food
- Recycling reduces pollution
- Money round the year
- Employment generation
- Increase input efficiency
- Standard of living of the farmer increased
- Better utilisation of land, labour, time and resources

Organic / eco-friendly agriculture - Dry farming - Concepts and principles

Organic farming: Organic farming is a production system where all kinds of agricultural products are produced organically, including grains, meat, dairy, eggs, fibers such as cotton, flowers and processed food products.

Organic farming avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators and livestock feed additives.

Need & scope of organic farming

- Increase in awareness and health consciousness
- Global consumers are increasingly looking for organic food, which is considered safe, and hazard free.
- The global prices of organic food are more lucrative and remunerative.
- The potential of organic farming is signified by the fact that the farm sector has abundant organic nutrient resources like livestock, water, crop residue, aquatic weeds, forest litter, urban, rural solid wastes and agro industries, bio-products.
- India offers tremendous scope for organic farming as it has local market potential for organic products

Principles (International Federation of Organic Agriculture Movements - IFOAM, 1972)

1. To produce food of high quality in sufficient quantity.
2. To interact in a constructive and life-enhancing way with natural systems and cycles.
3. To consider the wider social and ecological impact of the organic production and processing systems.

4. To encourage and enhance biological cycles within the farming system, involving micro-organisms, soil flora and fauna, plants and animals.
5. To maintain and increase the long-term fertility of soils.
6. To maintain the genetic diversity of the production system and its surroundings, including the protection of wildlife habitats.
7. To promote the healthy use and proper care of water, water resources and all life therein.
8. To use, as far as possible, renewable resources in locally organized production systems.
9. To give all livestock conditions of life with due consideration for the basic aspects of their innate behaviour.
10. To minimize all forms of pollution.
11. To allow every one involved in organic production and processing a quality of life which meets their basic needs and allows an adequate return and satisfaction from their work, including a safe working environment.
12. To progress towards an entire production, processing, and distribution chain which is both socially just and ecologically responsible.

Advantages of organic farming

- Nutrition - Improved soil health makes food dramatically superior in mineral content
- Poison-free - Free of contamination with health harming chemicals like pesticides, fungicides and herbicides.
- Food tastes better
- Food keeps longer - can be stored longer
- Disease and pest resistance - because of healthy plants
- Weed competitiveness - Healthier crops able to compete
- Lower input costs - No costly chemicals used, nutrients are created in-situ (in the farm)

- Drought resistance
- More profitable - Due to greater food value of organic produce consumers are willing to pay premium prices
-

Disadvantages of organic farming

- Productivity - Low productivity is often reported as the quantum nutrient used comparatively lower
- Labour intensive - Cultivation requires more labour especially for weed control
- Skill - requires considerable skill to farm organically Ex. Choice of alternatives for control of pests
- Lack of convenience in management compared to easier management like fertilizer application in conventional methods

Synonyms of organic farming

Eco-farming
Biological farming
Bio-dynamic farming
Macrobiotic agriculture

Eco-farming

- Farming in relation to ecosystem.
- It has the potential for introducing mutually reinforcing ecological approaches to food production.
- It aims at the maintenance of soil chemically, biologically and physically the way nature would do it left alone.
- Soil would then take proper care of plants growing on it.
- ***Feed the soil, not the plant*** is the watchword and slogan of ecological farming.
-

Biological farming

Farming in relation to biological diversity.

Biodynamic farming

Farming which is biologically organic and ecologically sound and sustainable farming.

Dryland Agriculture

Indian agriculture is predominantly a rainfed agriculture under which both dryfarming and dryland agriculture are included. Out of the 143 million ha of total cultivated area in the country, 101 million ha (i.e. nearly 70%) area are rainfed. In dryland areas, variation in amount and distribution of rainfall influence the crop production as well as socio-economic conditions of farmers. The dryland areas of the country contribute about 42% of the total food grain production. Most of the coarse grains like sorghum, pearl millet, finger millet and other millets are grown in drylands only. The attention has been paid in the country towards the development of dryland farming. Efforts were made to improve crop yields in research projects at Manjari, Solapur, Bijapur, Raichur and Rohtak. An all India co-ordinated research project for Dryland Agriculture was launched by ICAR in 1970 in collaboration with Government of Canada and later Central Research Institute for Dryland Agriculture (CRIDA) was established at Hyderabad.

Characteristics of Dryland Agriculture

Dry land areas may be characterized by the following features, 1. Uncertain, ill-distributed and limited annual rainfall 2. Occurrence of extensive climatic hazards like drought, flood etc. 3. Undulating soil surface 4. Occurrence of extensive and large holdings 5. Practice of extensive agriculture, i.e., prevalence of monocropping etc. 6. Relatively large size of fields 7. Similarity in types of crops raised by almost all the farmers of a particular region 8. Very low crop yield 9. Poor economy of the farmers

Dryland Agriculture

It is the profitable production of useful crops, without irrigation, on lands (arid and semi arid) that receive annual rainfall of less than 750mm

Rainfed Agriculture

It is the profitable production of useful crops, without irrigation, on lands (humid & subhumid regions) that receive annual rainfall of more than 750mm

fference between rainfed and irrigated igated farming

farming Rainfed farming	
In a certain part of the year crop is grown where rainfall received	Through out the year depending upon the water availability
Crops/crop varieties having drought tolerance or less water requirement are used	According to the need, crops or their varieties are selected
Duration of crops depends on the rainfall duration/ growing period most of the times short duration (LGP)	Depending upon the need
Mixed cropping is beneficial	Generally pure cropping is done
Due to limitation of moisture one or two crops in a year is possible	More than two crops in a year are grown, subject to availability of water
The field is ploughed to deep to increase infiltration of rains	No need for deep ploughing to conserve soil moisture
Land is prepared immediately after rainfall	Land is prepared according to optimum time of sowing
Risk of crop failure is expected due to insufficient soil moisture or drought	No risk of crop failure

AGRO-CLIMATIC ZONES OF INDIA AND ANDHRA PRADESH

Planning Commission has demarcated the geographical area of India into 15 agro-climatic regions. These are:

1. **Western Himalayan Region:** Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, Uttaranchal. The region consists of skeletal soils of cold region, podsolic soil, mountainous soil, hilly brown soil. Lands have steep slopes in undulating terrain.
2. **Eastern Himalayan Region:** Assam Sikkim, West Bengal and all North-Eastern states. These region falls under high rainfall and high forest cover. Shifting cultivation is

practiced in nearly one third of the cultivated area and this causes degradation of the soil, with heavy runoff, soil erosion and flood.

3. **Lower Gangetic Plains Region:** West Bengal, soils are mostly alluvial and are prone to floods.
4. **Middle Gangetic Plains Region:** Uttar Pradesh, Bihar. About 39 percent of the gross cropped area of this region is irrigated.
5. **Upper Gangetic Plains Region:** Uttar Pradesh. Irrigation is trough canals and tube wells. A good potential for exploitation of ground water.
6. **Trans-Gangetic Plains Region:** Punjab, Haryana, Delhi and Rajasthan. These regions have the highest sown areas, highest irrigated area, high cropping intensity and high ground water utilization.
7. **Eastern Plateau and Hills Region:** Maharashtra, Uttar Pradesh, Orissa and West Bengal. Irrigation is through canals and tanks. The soils are shallow and medium in depth.
8. **Central Plateau and Hills Region:** Madhya Pradesh, Rajasthan, Uttar Pradesh.
9. **Western Plateau and Hills Region:** Maharashtra, Madhya Pradesh and Rajasthan. The average rainfall of this zone is 904 mm.

10. **Southern Plateau and Hills Region:** Andhra Pradesh, Karnataka, Tamil Nadu. Dry farming is adopted and the cropping intensity is 111 percent.
11. **East Coast Plains and Hills Region:** Orissa, Andhra Pradesh, Tamil Nadu and Pondicherry. Irrigation is through canals and tanks.
12. **West Coast Plains and Ghats Region:** Tamil Nadu, Kerala, Goa, Karnataka, Maharashtra. Variety of cropping pattern, rainfall and soil types.
13. **Gujarat Plains and Hills Region:** Gujarat. This zone is arid with low rainfall in most parts. Irrigated through tube wells and wells.
14. **Western Dry Region:** Rajasthan. Hot sandy desert, erratic rainfall, high evaporation, scanty vegetation. The ground water is often deep and often brackish. Famine and drought are common features of this region.
15. **The Islands Region:** Andaman and Nicobar Islands, Lakshadweep. These regions are typical equatorial with rainfall of 3000 mm spread over eight to nine months. Largely forest zone with undulated land.

Agro climatic Zones of Andhra Pradesh

The cropped area in Andhra Pradesh is divided into seven zones based on the agro-climatic conditions. The classification mainly concentrates on the range of rainfall received, type and topography of the soils.

1. **Krishna – Godavari Zone**: It covers East Godavari Part, West Godavari, Krishna, Guntur, and contiguous areas of Khammam, Nalgonda and Prakasam. Rainfall of this zone is 800-1100mm. Soil type is deltaic alluvium, red soils with clay, red loams, coastal sands and saline soils. Paddy, Groundnut, Jowar, Bajra, Tobacco, cotton, chillies, Sugarcane and Horticultural Crops are the important crops grown.
2. **North Coastal Zones:** Covers Srikakulam, Vizianagaram, Visakhapatnam and uplands of East Godavari districts. This zone receives a rainfall of 1000-1100 mm mainly from south west monsoon. Soil type is red soils with clay base, pockets of acidic soils, laterite soils, Soils with PH 4-5. Main crops grown in these zones are Paddy, Groundnut, Jowar, Bajra, Mesta, Jute, Sun hemp, Sesame, Black gram and Horticultural Crops.
3. **Southern Zone**: Districts in this zone are Nellore, Chittoor, Southern parts of Prakasam and Cuddapah and Eastern parts of Anantapur. Rainfall received is about 700-1100 mm. Soil type is Red loamy soils, Shallow to moderately deep. Crops like Paddy, Groundnut,cotton Sugarcane. Millets and Horticultural Crops are mainly grown.

4. **North Telangana Zone**: Adilabad, Karimnagar, Nizamabad, Medak (Northern part), Warangal (Except N.W.Part), Eastern tips of Nalgonda and Khammam are the districts in this zone. Rainfall received is about 900-1500 mm. Soil type is Chalkas, Red sandy soils, Dubbas, Deep Red loamy soils, Very deep black cotton soils. Paddy,Sugarcane,Castor,Jowar, Maize, Sunflower, Tuemeric, Pulses and Chillies are the important crops.
5. **Southern Telangana Zone**: Hyderabad, Rangareddy, Mahabubnagar (except southern border), Nalgonda (except North eastern border), Medak (Southern parts), Warangal (North Western Part) are the districts covered. This zone receives a rainfall of about 700-900 mm. Soil type is red earth with loamy sub soil (Chalkas). Paddy, Sunflower, Safflower, Grapevine, Sorghum, Millets, Pulses and Orchard crops are the important crops.
6. **Scarce rainfall zone**: the districts covered are Kurnool, Anantapur, Prakasam (western parts), Cuddapah (Northern part), Mahabubnagar (Southern border). Receives a rainfall of 500-750 mm. Soil type is red earths with loamy soils (Chalkas), red sandy soils and black cotton soils in pockets. Cotton,Korra,Sorghum,Millets, Groundnut, Pulses, Paddy are the important crops.
7. **High altitude and Tribal areas**: Northern borders of Srikakulam, Vizianagaram and Visakhapatnam, East Godavari and Khammam are the districts covered. This zone receives a rainfall more than 1400 mm. Horticultural Crops, Millets, Pulses Chillies, Turmeric and Pepper are the important crops grown.