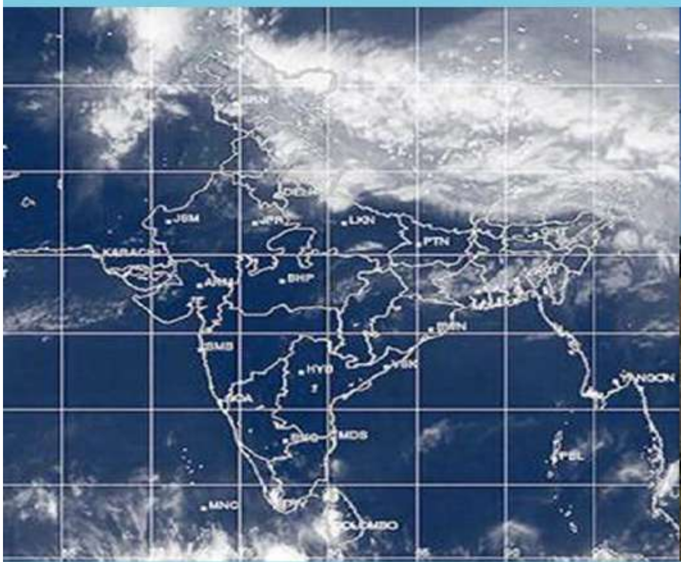
Development of e-Courses for B.Sc.(Agriculture) Degree Program



AGRO-101
Principles of Agronomy and Agricultural Meteorology

Principles Of Agronomy And Agricultural Meteorology

Author:- TNAU (ICAR)

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.

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

DEVELOPMENT OF SCIENTIFIC AGRICULTURE IN WORLD

Experimentation technique was started (1561 to 1624) by Francis Bacon. He conducted an experiment and found that water is the principle requirement for plant. If the same crop is cultivated for many times fertility is lost.

Jan Baptiste Van Helmont (1572-1644) was actually responsible for conducting a pot experiment. The experiment is called as 'willow tree experiment'. He took a willow tree of weight 5 pounds. He planted in a pot and the pot contained 200 pounds of soil and continuously monitored for five years by only watering the plant. By the end of 5th year, the willow tree was weighing 16 pounds. The weight of soil is 198 pounds. He concluded that water is the sole requirement for plants. The conclusion was erroneous.

In the 18th century, Arthur Young (1741-1820) published 'Annals of Agriculture'.

In the beginning of 19th century, scientist Jean Senebier (1742-1809), a Swiss naturalist, a historian, gave explanation that increase in the weight of plant was due to the consumption of air. Theodar Desaussure gave the principle theme of photosynthesis.

Liebig is a German scientist and considered as the 'Father of agricultural chemistry'. It was his opinion that the growth of plant was proportional to the amount of mineral substances available in the soil. This is called as 'Liebig law of minimum'.

Chronological events in scientific agriculture

Francis Bacon (1561-1624 A.D)	Found the water as nutrient of plants
G.R.Glanber (1604-1668 A.D)	Salt peter(KNO3) as nutrient and not water
Jethrotull (1674-1741 A.D)	Fine soil particle as plant nutrient
Priestly (1730-1799 A.D)	Discovered the oxygen
Francis Home (1775 A.D)	Water, air, salts, fire and oil form the plant nutrients
Thomas Jefferson (1793 AD)	Developed mould board plough
Theodore de-Saussure	Found that plants absorb CO_2 from air & release O_2; soil supply N_2
Justus van Liebig (1804- 1873)	German chemist developed "law of minimum "

Advances in Agriculture in 19th Century

Following Liebig, an agricultural experiment station was started in Rothamsted in England on 1843 (Old Permanent Manurial Experiment – OPME), it dealt with nutrients. Subsequently many developments took place. In U.S. land grant colleges was started in 19**th** century. Its objective was to meet the expenditure of the college from the land around the colleges. USDA (United States Department of Agriculture) is responsible for the introduction of herbicides 2,4-D and tractor combine for harvesting and threshing. Under Land Grant College, agriculture oriented teaching, research, extension are expanded. Many international research institutes were started for a specific crop.

- 1857–Michigan State University was established to provide agricultural education at college level.
- Gregor Mendal (1866) discovered the laws of hereditary.
- Charles Darwin (1876) published the results of experiments on cross and self fertilization in plants.
- Thomas Malthus (1898) proposed Malthusian Theory – states that humans would run-out of food for everyone inspite of rapid advance in agriculture due to limited land and yield potential of crops (i.e food may not be sufficient in future for the growing population at this current rate of growth in agriculture)
- Blackman (1905) theory of "optima and limiting factors" states that when a process is conditioned as to it's rapidity by a number of separate factors , the rate of the process is limited by the pace of the slowest factor"
- Mitscherlich (1909) proposed the theory of law of diminishing returns that increase in growth with each successive addition of the limiting element is progressively smaller and the response is curvilinear.
- Wilcox (1929) proposed "inverse yield nitrogen law". It states that the growth or the yielding ability of any crop plant is inversely proportional to the mean nitrogen content in the dry matter.

DEVELOPMENT OF SCIENTIFIC AGRICULTURE IN INDIA

Scientific agriculture got momentum in the 19th century itself. Indian Land Tax was levied in the middle of 19th century. In 1877, 1878, 1889, 1892, 1897 and 1900, the population was decreased due to continuous famines. Only due to these famines, the British regime started many development programmes. Lord Dalhousie (1848-1856) period the 'Upper Bari Doab Canal' in Punjab was constructed. Improvement of agriculture started only in his period. In Lord Curzon's (1898-1905) period, the 'Great Canal system of Western Punjab' was constructed. During his period Imperial Agricultural Research Institute was started in Pusa in Bihar. His period is called as 'Golden period of agriculture'. During his regime, Department of Agriculture and Agricultural colleges for provinces were started at Coimbatore in 1906.

Due to earthquake at IARI in Pusa, Bihar it was shifted to New Delhi. In 1926, Royal Commission on Agriculture was setup and was responsible for giving recommendation to dug canals, lay roads, etc. Based upon the recommendation of Royal Commission, ICAR (Imperial Council of Agricultural Research) was started in 1929 with the objective to conduct agriculture research. State Agricultural Universities (SAU) were started after 1960s). ICAR had also started research institutes of its own in different centres in India for various crops.

ICAR is the sole body, which controls all the Agricultural Research Institutes in India. It paved way for green revolution in India. After 1947, ICAR totally adapted to Land Grant Colleges. In 1962, a Land Grant College was started in Pantnagar (UP). It is the first university with 16,000 acres.

There are 45 state agricultural universities with research institutes on its own. High yielding wheat varieties like Kalyansona, Sonalika, Lerma roja and Sonara-64 were introduced. Green revolution took in wheat first, next in rice after the invention of Indo-*Japanica* variety. Today, agricultural research is multi-dimensional. In includes tissue culture, biotechnology besides breeding, crop production and crop protection.

Milestones

1880 - Department of Agriculture was established

1903 - Imperial Agricultural Research Institute (IARI) was started at Pusa, Bihar

1912 - Sugarcane Breeding Institute was established in Coimbatore

1929 - Imperial Council of Agricultural Research at New Delhi (then ICAR) after independence becomes ICAR

1936 - Due to earth quake in Bihar, IARI was shifted to New Delhi and the place was called with original name Pusa

1962- First Agricultural University was started at Pantnagar

1965-67 - Green revolution in India due to introduction of HYV –Wheat, rice, use of fertilizers, construction of Dams and use of pesticides

In Tamil Nadu

1876 - Madras Agricultural College was established at Saidapet

1906 - Agricultural College & Research Institute was established at Coimbatore

1971 - Tamil Nadu Agricultural University was started

For institutes visit http://www.icar.org.in/node/325

For state agricultural universities visit http://www.icar.org.in/en/universities.htm

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Institutions - 45

1. Central Rice Research Institute, Cuttack
2. Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
3 Indian Institute of Pulses Research, Kanpur
4. Central Tobacco Research Institute, Rajahmundry
5. Indian Institute of Sugarcane Research, Lucknow
6. Sugarcane Breeding Institute, Coimbatore
7. Central Institute of Cotton Research, Nagpur
8. Central Research Institute for Jute and Allied Fibres, Barrackpore
9. Indian Grassland and Fodder Research Institute, Jhansi
10. Indian Institute of Horticultural Research, Bangalore
11. Central Institute of Sub Tropical Horticulture, Lucknow
12. Central Institute of Temperate Horticulture, Srinagar
13. Central Institute of Arid Horticulture, Bikaner
14. Indian Institute of Vegetable Research, Varanasi
15. Central Potato Research Institute, Shimla
16. Central Tuber Crops Research Institute, Trivandrum
17. Central Plantation Crops Research Institute, Kasargod
18. Central Agricultural Research Institute, Port Blair
19. Indian Institute of Spices Research, Calicut
20. Central Soil and Water Conservation Research & Training Institute, Dehradun
21. Indian Institute of Soil Sciences, Bhopal
22. Central Soil Salinity Research Institute, Karnal
23. ICAR Research Complex for Eastern Region including Centre of Makhana, Patna
24. Central Research Institute of Dryland Agriculture, Hyderabad
25. Central Arid Zone Research Institute, Jodhpur
26. ICAR Research Complex Goa
27. ICAR Research Complex for NEH Region, Barapani
28. National Institue of Abiotic Stress Management, Malegaon, Maharashtra
29. Central Institute of Agricultural Engineering, Bhopal
30. Central Institute on Post harvest Engineering and Technology, Ludhiana
31. Indian Institute of Natural Resins and Gums, Ranchi
32. Central Institute of Research on Cotton Technology, Mumbai
33. National Institute of Research on Jute & Allied Fibre Technology, Kolkata
34. Indian Agricultural Statistical Research Institute, New Delhi
35. Central Sheep and Wool Research Institute, Avikanagar, Rajasthan
36. Central Institute for Research on Goats, Makhdoom
37. Central Institute for Research on Buffaloes, Hissar
38. National Institute of Animal Nutrition and Physiology, Bangalore
39. Central Avian Research Institute, Izatnagar
40. Central Marine Fisheries Research Institute, Kochi
41. Central Institute Brackishwater Aquaculture, Chennai
42. Central Inland Fisheries Research Institute, Barrackpore
43. Central Institute of Fisheries Technology, Cochin
44. Central Institute of Freshwater Aquaculture, Bhubneshwar
45. National Academy of Agricultural Research & Management, Hyderabad

National Research Centres - 17

1. National Research Centre on Plant Biotechnology, New Delhi
2. National Centre for Integrated Pest Management, New Delhi
3. National Research Centre for Litchi, Muzaffarpur

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4. National Research Centre for Citrus, Nagpur
5. National Research Centre for Grapes, Pune
6. National Research Centre for Banana, Trichi
7. National Research Centre Seed Spices, Ajmer
8. National Research Centre for Pomegranate, Solapur
9. National Research Centre on Orchids, Pakyong, Sikkim
10. National Research Centre Agroforestry, Jhansi
11. National Research Centre on Camel, Bikaner
12. National Research Centre on Equines, Hisar
13. National Research Centre on Meat, Hyderabad
14. National Research Centre on Pig, Guwahati
15. National Research Centre on Yak, West Kemang
16. National Research Centre on Mithun, Medziphema, Nagaland
17. National Centre for Agril. Economics & Policy Research, New Delhi

Important International Institutions on Agricultural Research

AVRDC- Asian Vegetable Research and Development Centre, Taiwan
CIAT – Centro International de Agricultura Tropical , Cali, Colombia
CIP – Centro International da la Papa (International potato research institute (Lima, Peru, South America)
CIMMYT – Centro International de Mejoramiento de Maizy Trigo.(International Centre for maize and Wheat development (Londress, Mexico)
IITA –International Institute for Tropical Agriculture, Ibadon in Nigeria, Africa)
ICARDA – International Center for Agricultural Research in the Dry Areas (Aleppo, Syria)
ICRISAT – International Crops Research Institute for the Semi Arid Tropics (Pattancheru in Hyderabad, India)
IIMI- International Irrigation Management Institute, Colombo, SRILANKA
IRRI – International Rice Research Institute (Los Banos, Philippines)
ISNAR- International Service In National Agricultural Research The Hague, Netherlands
WARDA - West African Rice Development Association Ivory coast, Africa.
IBPGR - International Board for Plant Genetic Resources, Rome, Italy
CGIAR – Consultative Group on International Agricultural Research, Washington D.C
FAO – Food and Agricultural Organization, Rome
WMO- World Meteorological Organization, Vienna.

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. The information related to the biodiversity and agriculture (including animal husbandry) are available in these texts.

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 depended upon the 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.

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.

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 (1^{st}-2^{nd} 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.

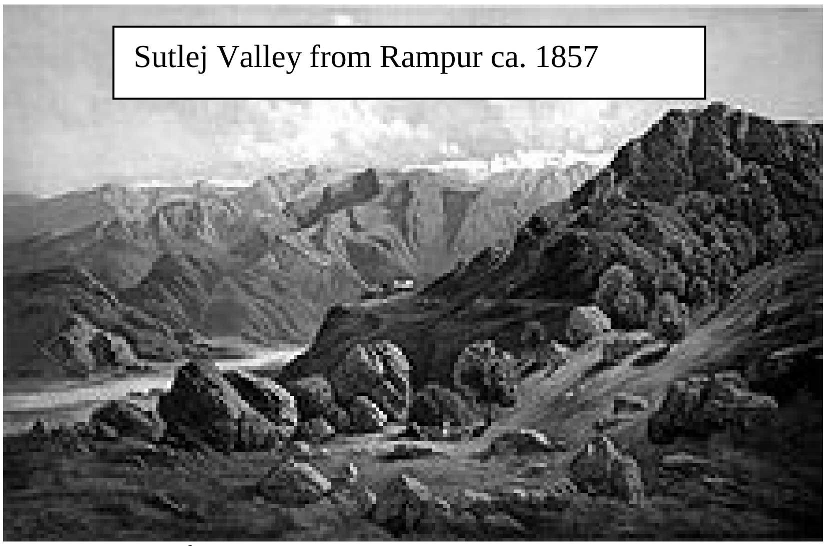
- **320-550 CE:** Crystallized sugar was discovered by the time of the Guptas and the earliest reference of candied sugar come from India.
- **647 CE:** Chinese documents confirm at least two missions to India, initiated in, for obtaining technology for sugar-refining.
- **875-1279 CE :** Noboru Karashima's 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)

Sutlej Valley from Rampur ca. 1857

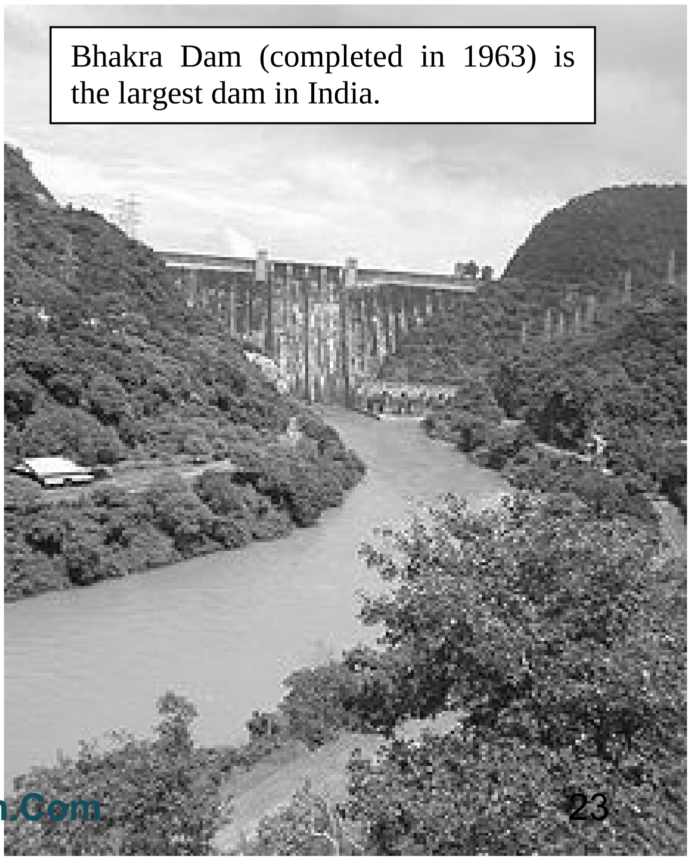


- A number of irrigation canals are located on the Sutlej river.
- Few Indian commercial crops—such as Cotton, indigo, opium, and rice—made it to the global market under the British Raj in India.
- The second half of the 19th century saw some increase in land under cultivation and agricultural production 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.



Bhakra Dam (completed in 1963) is the largest dam in India.

- 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

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

Kautilya's Arthasasthra - Sangam literature - rainfall prediction – ITK -Tamil Almanac.

Agriculture in Arthasasthra

Kautilya (also known as Vishnu Gupta or Chanakya) (321-296 BC) was a great scholar of time. He wrote a treatise titled, Arthasasthra, which deals with the management of resources. During Kautilya's time agriculture, cattle breeding and trade were grouped into a science called 'Varta'. Kautilya gave great importance to agriculture and suggested a separate post of head of agriculture and named as 'Sitadhakashya'. Agriculture today receives prime importance, by policy and administrative support from government officials. eg. i) Supply of good seeds and other inputs, ii) Provision of irrigation water, iii) prediction of rainfall by IMD, iv) Assistance in purchase of machineries, v) Marketing and safe storage. All the important aspects are mentioned by Kautilya in his book. He suggested many important aspects in agriculture which are highly relevant today.

1. The superintendent of agriculture should be a person who is knowledgeable in agriculture and horticulture. There was a provision to appoint a person who was not an expert but he was assisted by other knowledgeable person.
2. Anticipation of labours by land owners before sowing. Slaves and prisoners were organised to sow the seeds in time. He also emphasized that ploughing provides good soil texture required for a particular crop.
3. Timely sowing is very important for high yield particularly for rainfed sowing for which, all the implements and accessories have to be kept ready. Any delay in these arrangements received punitive action.
4. Kautilya suggested that for getting good yield of rainfed crop, a rainfall of 16 dronas (One drona = 40 mm to 50 mm; so totally 600-800 mm) was essential and 40 dronas rainfall (1600-200 mm) is sufficient for rice. It is very significant to note that rain gauge was used during Kautilya's period. It was apparently a circular vessel (20 fingers width, 8 fingers depth) and the unit to measure rain was adhaka (1 adhaka=12 mm approx.)
5. He also stressed the optimum distribution of rainfall during crop growing season. One third of the required quantity of rainfall must fall both in the commencement (July/August) and closing months (October-December) of rainy season; and 2/3 of rainfall in the middle (August-October) is considered as very even.
6. The crops should be sown according to the the season. E.g. *Sali* (transplant rice), *Virlu* (direct sown rice), *Till* (Sesame) and millets should be sown at the commencement of rain. Pulses to be sown in the middle of season. Safflower, linseed, mustard, barley and wheat to be sown later.
7. He also stressed that rice crop require less labour expense, vegetables are intermediate and sugarcane is worst as it requires more attention and expenditure.
8. The crops like cucurbits are well suited to banks of rivers, Long-peper, sugarcane and grapes do well where the soil profile is well charged with water. Vegetable require frequent irrigation, borders of field suited for cultivation of medicinal plants.
9. Some of the bio-control practices suggested by Kautilya has got relevance. They are:
   a) Practice of exposing seeds to mist and heat for seven nights. These practices are followed even now in wheat to prevent smut diseases.
   b) Cut ends of sugarcane are plastered with the mixture of honey, ghee and cow-dung. Recently evidences proved that honey has widely an antimicrobial property. Ghee could seal off the cut ends prevent loss of moisture and cow-dung facilitated bio-control of potential pathogens.

10. He also suggested that harvesting should be done at proper time and nothing should be left in the field not even chaff. The harvested produce should be properly processed and safely stored. The above ground crop residues were also removed from fields and fed to cattle.

Agriculture in the Sangam literature

During the Sangam period (200 BC to 100 AD), the main profession of the population of the Tamil region (now Tamil Nadu) was agriculture. The region extended from Cape Comorin (Kanniyakumari) in the South to Tirupati (in Andhra Pradesh) in the North, parts of present Kerala and Karnataka in the West. The methods of cultivation practised during this ancient period were revealed by several proverbs, village songs and literature of the period which are available even today. It is rather surprising that the people had good knowledge about agriculture (seed varieties, seed selection, seed storage, ploughing, manuring, irrigation, weeding, crop protection, pests, and botanical pesticides).

The Sangam period literature covers wide aspects of the people's life, such as epics, ethics, social life and religion. Several poems composed during this period have been passed on from generation to generation through memorizing and chanting and later through manuscripts written on *Palmyara* leaves. With the advent of paper and printing machinary, Shri Swaminatha Iyer who is popularly called 'Tamill grandfather' painstakingly collected them and brought them out as printed books. Two peoms of the Sangam period, viz., Tholkappiyam and Thirukural, gives us a vivid picture of agricultural practices in that period.

Tholkappiyam

The poem Tholkapiyam was written by the poet Tholkappier during 200 BC. It gives descriptions of various agricultural aspects and these are enumerated below.

Land classification

Land was classified into five (but, cultivable land in to four) groups, viz., *Mullai* (forest), *Kurinji* (hills), *Marudham* (cultivable lands), and *Neithal* (coastal areas). *Palai* land was not brought under cultivation and left as fallow.

Seasons

Six seasons are mentioned: Early spring, late spring, cloudy, rainy, early winter, and late winter.

Cultivated crops

There are references to rice, millets, sugarcane, banana, cardamom, pepper, cotton, sesame, coconut and nut. Farmers were aware that rice could be grown as rainfed crops. Banana and sugarcane were ratooned. Plants were considered as living beings and endowed with sensitivity. Tholkappier also mentioned about monocots and dicots.

Importance of agriculture

Kings considered agricultural development as their primary duty. They felt that soil fertility and irrigation facilities should be the country's assets. Increased agricultural production was considered a yardstick of prosperity of the country. The stability of a kingdom was ensured not by army but by agriculture and sufficient crop production. Failure of monsoon rains and reduction in grain yield were attributed to the king's sins.

Irrigation

Kings dug-out tanks at locations where water flow from rains was plentiful. Semicircular bunds were raised adjacent to small hillocks and water reservoirs akin to present day dams were raised and constructed. It indicates awareness of water harvesting. The king 'Karikal Cholan' brought 1000 slaves from a conquered country and raised the bunds of river Cauvery. The stone dam constructed across the river Cauvery centuries ago is considered a master piece of engineering even today. River water was diverted to tanks through canals. It is mentioned that irrigation should be given both in early morning or late evening, and not during hot mid-day.

Agricultural implements

Buffaloes were used for ploughing with a wooden plough. Deep ploughing was considered superior to shallow ploughing. A labour saving tool called *Parambu* was used for leveling paddy fields. Tools such as *Amiry*, *Keilar*, and *Yettam* were used to lift water from wells, tanks, and rivers. Tools called *Thattai* and *Kavan* were used for scaring birds in millet fields. Traps were used to catch wild boars in millet fields.

Seeds

Seed was selected from those earheads that first matured. The selected seed was stored for sowing only and never used as food grain. It was believed that such a diversion would destroy the family.

Crop rotation

Crop rotation was practised by raising black gram (urd) after rice. This indicates that farmers were aware of the benefits to the following rice crop which we now know is due to the nitrogen fixation in the root nodules of urd. They also practised mixed cropping; e.g., foxtail millet with lablab or cotton.

Threshing

A tool called *Senyam* was used for harvesting rice. Threshing of rice was done by hand with the help of a buffalo (and in large holdings by elephants). Hand winnowing was done to remove chaff. One sixth of the produce was paid as tax to the king. Farm labourers were paid in kind.

The land was immediately ploughed after harvest or water was allowed to the field to facilitate rooting of stubbles. Operations requiring hard work such as ploughing were done by men while women attended to light work such as transplanting, weeding, bird scaring, harvesting and winnowing. In Kandapuranam, it is mentioned that Valli, daughter of a king, was sent for bird scaring in millet fields where Lord Muruga (son of Lord Shiva) courted her and married.

Marketing

Products were exchanged by weight. In Madurai (the headquarters of Sangam poets), there was a food grain bazaar where 18 kinds of cereals, millets and pulses were sold. Each shop had a banner hoisted high so that it could be seen from a distance indicating that the grains are sold here. Customs duty was collected on imports and exports.

Thirukural

The poem was composed by a gifted poet named *Thiruvalluvar* during 70 BC. It consists of 1330 couplets (133 topics each having 10 couplets). It is the pride of Sangam Tamil literature and its greatness can be realized from the fact that it has been translated into English and several other languages. It devotes one topic (10 couplets) for agriculture under the chapter politics. This clearly reveals the recognition that the prime duty of a king is to ensure agricultural production.

Importance of agriculture

'World spins around many industries. All such industries spin around agriculture'

'Farmers alone live an independent life; others worship them and are second to them'

'If farmers stop cultivation, even rishis (sages) cannot survive'

Ploughing

'If land is ploughed deep and soil allowed drying to one fourth weight, even manuring is not necessary'

Manuring

'Manuring is more important than ploughing: crop protection is more important than irrigation'. Green leaf manuring, farmyard manure, and sheep penning were in vogue though farmers were not aware that they supplied nitrogen to the crop. One is amazed at the depth of agricultural knowledge our ancestors possessed.

Irrigation

Bed method was followed as an efficient method of water management.

Weeding

'Just like the farmer pulls out weeds with the root system, so the king should eliminate criminals from society'.

Care of crops

'If the farmer does not regularly visit his field, the crop will not grow'

The foregoing account of agriculture from ancient Tamil literature clearly indicates the agricultural knowledge of our forefathers. By following their footsteps, the present generation of agricultural scientists has used the advanced technologies and has tried to stabilize agricultural production in our country to meet our food requirements.

Rainfall prediction

- Large number of fireflies seen at night on the forest trees is a sign that the monsoon will start early (Farmers in Maharashtra).
- If there is rain, accompanied with lightning and mild thunder on the second day of Jayastha month (May – June), there will be no rain for the next 72 days (Farmers Gujarat)

Indigenous Technical Knowledge (ITK)

ITK is defined as the sum total of knowledge and practices which are based on people's accumulated experience in dealing with situations and problems in various aspects of life and such knowledge and practices are special to a particular culture.

When the farmers continuously practicing indigenous knowledge, it will be also relevant to enquire why they do so. In other words, what are the advantages of such practices as perceived by farmers? Understanding the rational of such practices from farmers' point of view, may also help researchers to look into the valid factors while they research to farmers need and help extension workers to select appropriate technologies based on few criteria

- Summer ploughing conserves moisture, eradicates weeds, consolidates soil erosion and minimizes the number of ploughings at the time of sowing.
- Due to cowdung coating for cotton seeds, the easy dibbling of seeds to remove fuzz, good germination, no cost and pest-reduction were the advantages.
- Soaking sorghum seeds in cow urine before sowing increase the drought tolerance and the seeds had germination with minimum rain and it was considered as no cost practice.
- Soaking Bengal gram in water **a**s found with the previous practice, farmers had resorted to the practice of soaking bengal gram in water before sowing because it considered as no cost and withstanding water stress.
- Cotton seeds treated with red soils facilitate easy dibbling of seeds and it favours good germination.
- Cattle penning practices improve the soil fertility owing to organic manure.
- Sorghum mixed with lab-lab given additional yield owing to mixed cropping and it enhances nitrogen fixation by leguminous lab-lab.
- Use of cow dung cake as burrow fumigant is economical in controlling rats.

- Raising castor as a border crop in cotton field is used as trap crop for the cotton pest and it also provided additional income.
- Easy removal of pest, easy separation of kernels, longer shelf life and higher economics are advantages of coating red gram with red soil.
- Mixing green gram with ash was one of the post harvest indigenous practice and it had certain advantages like pest reduction and cheaper method.

Tamil Almanac (*Panchangam*)

An annual publication including weather forecasts and other miscellaneous information arranged according to the calendar of a given year

The Tamil Almanac is used in Tamil Nadu and Puducherry in India, and by the Tamil population in Malaysia, Singapore and Sri Lanka. It is used today for cultural, religious and agricultural events, with the Gregorian calendar having largely supplanted it for official use both within and outside India. It is based on the classical Hindu solar calendar also used in Assam, Bengal, Kerala, Manipur, Nepal, Orissa and the Punjab.

There are several festivals based on the Tamil Hindu calendar. The Tamil New Year follows the *Nirayanam* vernal equinox and generally falls on April 13 or 14th of the Gregorian year. April 13 or 14th marks the first day of the traditional Tamil calendar and this remains a public holiday in both Tamil Nadu and Sri Lanka. Tropical vernal equinox fall around 22 March, and adding 23 degrees of trepidation or oscillation to it, we get the Hindu sidereal or *Nirayana Mesha Sankranti* (Sun's transition into *nirayana* Aries).

Hence, the Tamil calendar begins on the same date in April which is observed by most traditional calendars of the rest of India.

Week

The days of the Tamil calendar relate to the celestial bodies in the solar system: Sun, Moon, Mars, Mercury, Jupiter, Venus, and Saturn, in that order. The week starts with Sunday.

This list compiles the days of the week in the Tamil calendar:

No.	Weekday (Tamil)	Sanskrit name	Lord or Planet	Gregorian Calendar equivalent
01.	*Gnyaayitru-kizhamai*	Ravivaara	Sun	Sunday
02.	*Thingat-kizhamai*	Somavaara	Moon	Monday
03.	*Sevvaai-kizhamai*	Mangalavaara	Mars	Tuesday
04.	*Buthan-kizhamai*	Budhavaara	Mercury	Wednesday
05.	*Viyaazha-kizhamai*	Guruvaara	Jupiter	Thursday
06.	*Velli-kizhamai*	Sukravaara	Venus	Friday
07.	*Sani-kizhamai*	Shanivaara	Saturn	Saturday

Months

The number of days in a month varies between 29 and 32.

The following list compiles the months of the Tamil Calendar

No.	Month (Tamil)	Sanskrit Name	Gregorian Calendar equivalent
01.	*Cittirai*	*Chaitra*	mid-April to mid-May
02.	*Vaikaci*	*Vaisakha*	mid-May to mid-June

03.	*Aani*	*Jyaishtha*	mid-June to mid-July
04.	*Aadi*	*Ashadha*	mid-July to mid-August
05.	*Aavani*	*Shravana*	mid-August to mid-September
06.	*Puraṭṭaci*	*Bhadrapada*	mid-September to mid-October
07.	*Aippaci/Aippasi*	*Ashwina*	mid-October to mid-November
08.	*Karttikai*	*Karttika*	mid-November to mid-December
09.	*Markaḻi*	*Margashirsha*	mid-December to mid-January
10.	*Tai*	*Pausha*	mid-January to mid-February
11.	*Maci*	*Magha*	mid-February to mid-March
12.	*Pankuni*	*Phalguna*	mid-March to mid-April

Seasons

The Tamil year, in keeping with the old Indic calendar, is divided into six seasons, each of which lasts two months

Season name	English translation	Sanskrit Name	English equivalent	Months
Kar	Dark, rain	Varsha	Rainy	Aavani, Purataci
Kutir	Chill, wind	Sharada	Autumn	Aippaci, Kārthikai
Munpani	Early dew	Hemanta	Early winter	Markazhi, Tai
Pinpani	Late dew	Sishira	Late winter	Masi, Pankuni
Ilavenil	Young warmth	Vasanta	Spring	Chithirai, Vaikasi
Mutuvenil	Extreme warmth	Grishma	Summer	Aani, Aadi

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

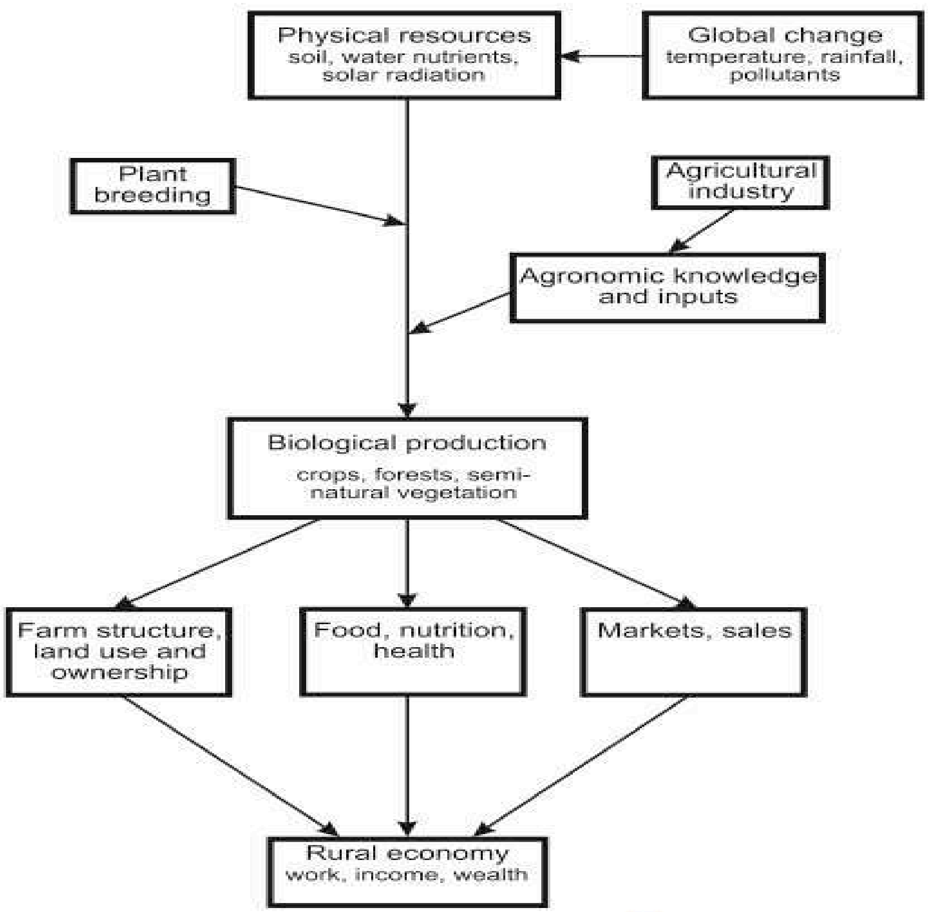
Agronomy is derived from a Greek word '**agros'** meaning 'field' and '**nomos'** meaning 'management'. Principles of agronomy deal with scientific facts in relations to environment in which crop are produced.

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.



Flow diagram of physical, biological, economic and social dimensions of agronomy

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 $1/3^{rd}$ 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

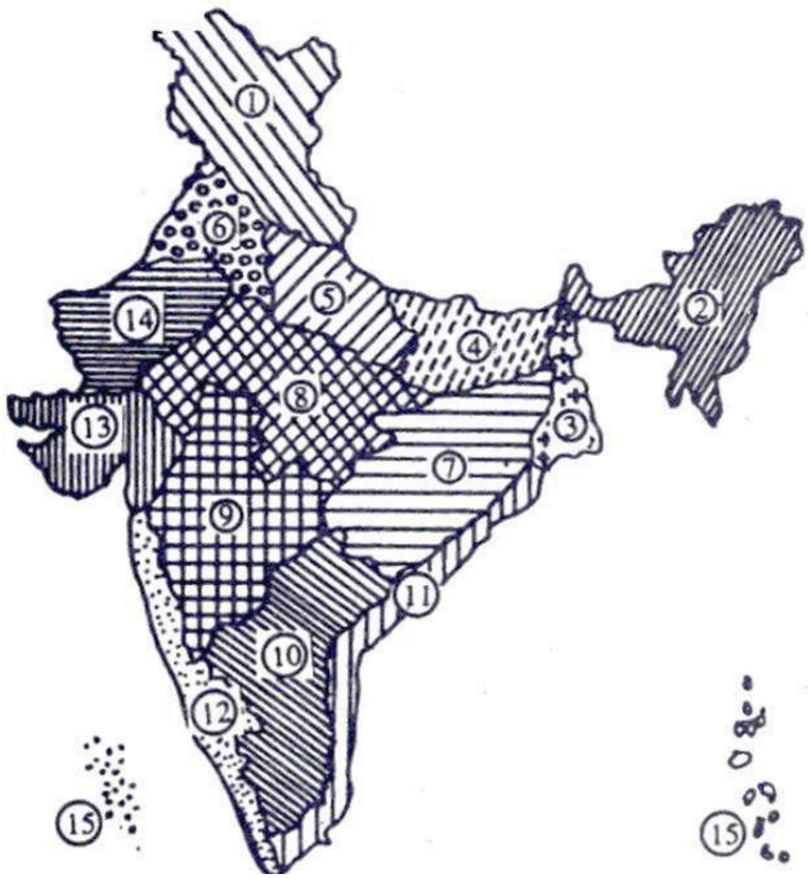
This zone consists of 19 districts of Gujarat. This zone is arid with low rainfall in most parts and only 32.5% of the area is irrigated largely through wells and tube wells.

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

13	Gujarat Plains and Hills Region	Gujarat
14	Western Dry Region	Rajasthan
15	The Islands Region	Andman & Nicaobar, Lakshya Deep

Classification by ICAR

The State Agricultural Universities were advised to divide each state into sub-zones, under the National Agricultural Research Project (NARP) under ICAR. Based on the rainfall pattern, cropping pattern and administrative units, 127 agro-climatic zones are classified. The zones of each state are given below.

State	No. of zones	State	No. of zones
Andhra Pradesh	7	Madhya Pradesh	12
Assam	6	Rajasthan	9
Bihar	6	Maharashtra	9
Gujarat	8	North Eastern Hill region	6
Haryana	2	Orissa	9
Himachal Pradesh	4	Punjab	5
Jammu and Kashmir	4	Tamil Nadu	7
Karnataka	10	Uttar Pradesh	10
Kerala	8	West Bengal	6

The state of Tamil Nadu has been classified into seven distinct agro-climatic zones listed below.

1. North Eastern zone
2. North Western zone
3. Western zone
4. Cauvery Delta zone
5. Southern zone
6. High Rainfall zone
7. Hilly zone

1. North Eastern zone

This zone covers the districts of Thiruvallur, Vellore, Kanchipuram, Thiruvannamalai, Viluppuram, Cuddalore (excluding Chidambaram and Kattumannarkoil taluks), some parts of Perambalur including Ariyalur taluks and also Chennai. The mean annual rainfall of this region is 1054 mm received in 53 rainy days and is benefited by both the monsoons. The mean monthly maximum temperature ranges between 28.2 to 38.9 °C and the minimum ranges from 19.5 to 24.8°C.

2. North Western zone

This zone comprises of Dharmapuri and Krishnagiri district (excluding hilly areas), Salem, Namakkal district (excluding Tiruchengode taluk) and Perambalur taluk of Perambulur district. The climate prevailing in this region is dry and sub humid. This region has been identified as moderately drought prone area. The elevation varies from 330 to 1070 m above mean sea level. The mean annual rainfall of this region is appreciably lower than in North Eastern zone and is 825 mm received in 47 rainy days. The region is benefited by both south-west and north-east monsoon rains but unlike the NEZ, the former contributed more to the total rainfall. The mean monthly maximum temperature ranges between 30 to 37°C with minimum temperature ranging between 19 to 25.5°C. The annual PET of this region is 1727 mm compared to the annual precipitation of 825 mm.

3. Western zone

This zone comprises of Erode, Coimbatore, Dindigal, Theni districts, Tiruchengode taluk of Namakkal district, Karur taluk of Karur district and some western part of Madurai district. The mean annual rainfall is 718 mm in 45 rainy days. The monthly mean maximum temperature is 35°C in April and 30°C in January and November. The monthly mean minimum temperature is 19°C in January and 24°C in May.

4. Cauvery Delta zone

This zone comprises the Cauvery Delta area in Thanjavur, Thiruvarur, Nagapattinam districts and Musiri, Tiruchirapalli, Lalgudi, Thuraiyur and Kulithalai taluks of Tiruchirapalli district, Aranthangi taluk of Pudukottai district and Chidambaram and Kattumannarkoil taluks of Cuddalore district. The mean annual rainfall of the zone is 1078 mm out of which 40mm is received during winter, 69.2mm during summer, 295.4mm during South West Monsoon and 673.8mm during North East Monsoon.

5. Southern zone

This is the biggest among the seven zones of Tamil Nadu. It is typical zone surrounded by coastal areas on the East and mountains in the West. This zone comprises Sivagangai, Ramanathapuram, Virudunagar, Tuticorin and Tirunelveli districts and Natham and Dindigul taluks of Dindigul district, Melur, Tirumangalam, Madurai South and Madurai North taluks of Madurai district and Pudukkottai district excluding Aranthangi taluk. This zone lies on the Southern part of the State under rain shadow area. Because of this, the area is prone to drought very often. The climate is semi-arid tropics. The elevation varies from mean sea level to 300 m. The mean annual rainfall is 776 mm received in 43 rainy days. The monthly mean maximum temperature in this region ranges from 28.5°C in December to 38.5°C in June. The monthly mean minimum temperature varies from 21.0°C in January to 27.5°C in June.

6. High rainfall zone

This zone consists of Kanayakumari district. This district situated in the southern most part of the Peninsular India, with its high rainfall having a climate which is entirely different from the rest of the state. The climate is monsoon tropics and there is seasonal in shores flow of moist air. The elevation ranges from sea level to about 600 m. The mean annual rainfall of the district is 1469 mm received in 64 rainy days. There is not much fluctuation in the mean monthly air temperature. The monthly mean maximum temperature varies from 28.0°C in December to 33.5°C in May. The monthly mean minimum temperature varies from 22°C in December to 26.5°C in May.

7. High altitude and Hilly zone

This zone comprises the hilly regions, namely the Nilgiris, Shevroys, Elagiri-Javvadhu, Kollimalai, Patchaimalai, Anamalais, Palanis and Podhigaimalais. The rainfall varies from 850 mm in Kalrayan hills to about 4500 mm in Anamalai hills.

Agro-ecological zones of India

An ecological region is characterized by distinct ecological responses to macroclimate as expressed in vegetation and reflected in soils, fauna and aquatic systems. Therefore, an agro-ecological region is the land unit on the earth’s surface carved out of agro-climatic region when superimposed on different landform and soil conditions that act as modifiers of climate and length of growing period (LGP).

National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) of the ICAR has delineated 20 agro-ecological regions (AERs) in the country using the FAO 1978 concept of superimposition of length of growing periods and bio-climate maps on soil physiographic map.

Arid ecosystem

1. Western Himalayas, cold eco-region, shallow soils, LGP <90 days.
2. Western plain Kachohh and parts of Kathiawar Peninsula, hot arid eco-region, desert and saline soils. LPG <90 days.
3. Deccan plateau, hot arid ecoregion, red and black soils. LGP <90 days.

Semiarid ecosystem

4. Northern plain and central high lands, hot semiarid eco-region, alluvial soils. LGP 90-150 days.
5. Central high lands, Gujarat plains, Kathiawar peninsula, hot semiarid eco-region, medium and deep black soils. LGP 90-150 days.
6. Deccan plateau, hot semiarid ecoregion. LGP 90-150 days.
7. Telangana, Eastern ghats, hot semiarid eco-region. LGP 90- 150 days.
8. Eastern ghats, Tamil Nadu uplands and Karanataka plateau, hot semiarid eco-region. LGP 90-150 days.

Subhumid Ecosystem

9. Northern plain, hot sub-humid (dry) eco-region, red and black soils. LGP 150-180 days.
10. Central highlands, hot sub-humid eco-region, black and red soils. LGP 150-180 (210) days.
11. Eastern plateau, hot sub-humid eco-region, red and yellow soils, (210) days. LGP 150-180 days.
12. Eastern plateau (Chotanagpur) and Eastern ghats hot sub-humid eco-region, red and lateritic soils. LGP 150-180 (210) days.
13. Eastern plain, hot sub-humid (moist) eco-region, alluvial soils. LGP 180-210 days.
14. Western Himalayas, warm sub-humid to humid eco-region with brown forest soils. LGP 180-210+ days.

Humid-Perhumid ecosystem

15. Bengal and Assam plain hot sub-humid (moist) to humid eco-region, alluvial soils. LGP 210+ days.
16. Eastern Himalayas, warm per-humid eco-region, brown and red hill soils. LGP 210 + days.
17. North eastern hills, warm per-humid eco-region, red and lateritic soils. LGP 210+ days.

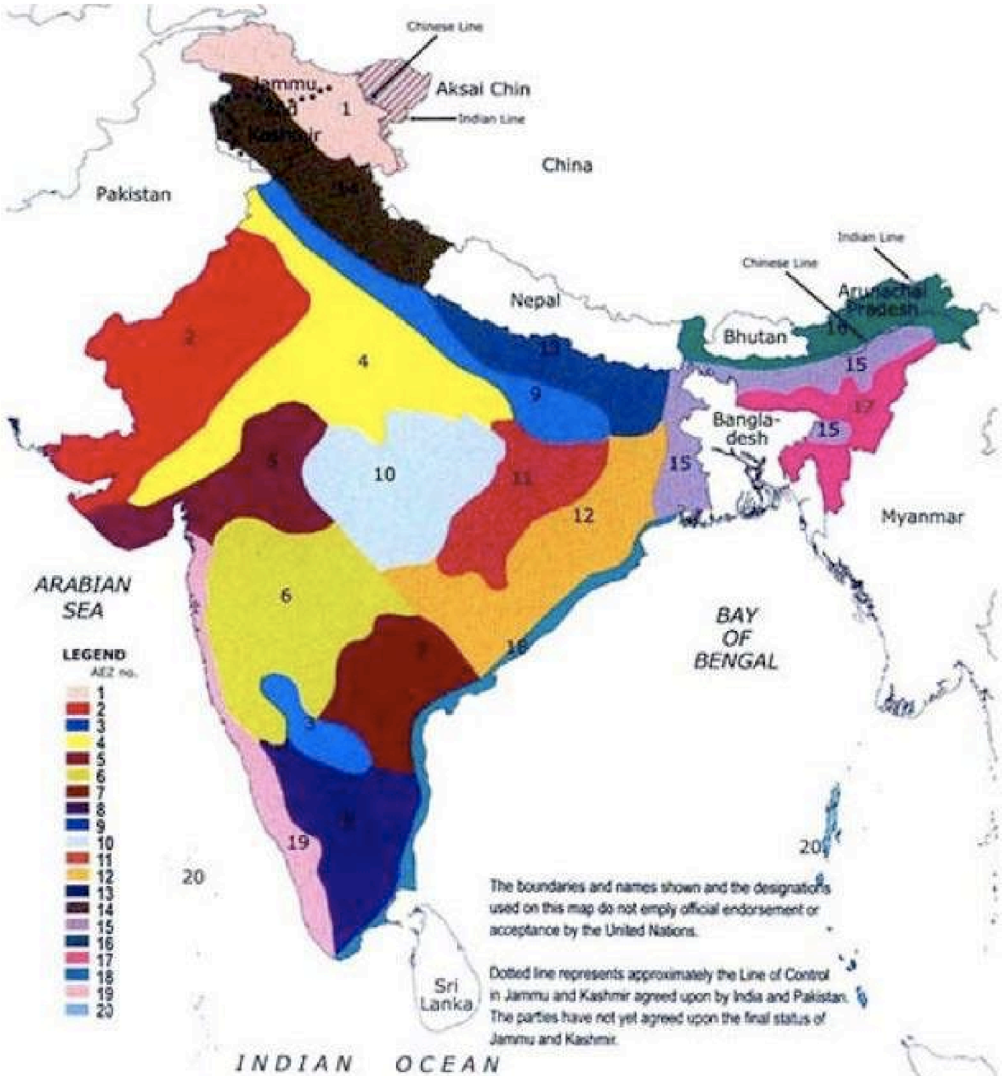
Coastal Ecosystem

18. Eastern coastal plain, hot sub-humid to semiarid eco-region, coastal alluvium. LGP 90-210 +days.
19. Western Ghats and coastal plain, hot humid-per-humid eco-region, red, lateritic and alluvium derived soils. LGP 210+ days.

Island Ecosystem

20. Andaman Nicobar and Lakshadeep, hot humid to per-humid eco-region, real loamy and sandy soils. LGP 210+ days.

The major advantage of LGP based criteria is that the LGP is the direct indicative of moisture availability of a given landform rather than the total rainfall. For example, both Ratnagiri in western Maharashtra and Nagpur in eastern Maharashtra have LGP 180-210 + days but the total annual rainfall of Ratnagiri is more than 2000 mm where as that of Nagpur is only 1100 mm. Therefore, agro-ecosystems approach allows crop planning based on length of growing period rather than the quantity of rainfall.



Chinese Line
Aksai Chin
Indian Line
China
Pakistan
Nepal
Indian Line
Chinese Line
Arunachal Pradesh
Bhutan
Bangla-desh
Myanmar
ARABIAN SEA
BAY OF BENGAL
LEGEND
AEZ no.
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Sri Lanka
INDIAN OCEAN
The boundaries and names shown and the designations used on this map do not emply official endorsement or acceptance by the United Nations.
Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The parties have not yet agreed upon the final status of Jammu and Kashmir.

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*

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:

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

Tribe	Hordeae	-
Genus	*Triticum*	*Medicago*
Species	*aestivum*	*sativa*

4. Based on seasons

Crops are grouped under the seasons in which their major field duration falls.

a) Kharif crops: Crops grown during June-July to September–October which require a warm wet weather during their major period of growth and shorter day length for flowering.

Ex. Rice, maize, castor, groundnut.

b) Rabi crops: Crops grown during October–November to January-February, which require cold dry weather for their major growth period and longer day length for flowering.

Ex. Wheat, mustard, barley, oats, potato, bengal gram, berseem, cabbage and cauliflower.

c) Summer crops: Crops grown during February–March to May–June which require warm dry weather for growth and longer day length for flowering. Ex.Black gram, greengram, seasome, cowpea etc.

This classification is not a universal one. It only indicates the period when a particular crop is raised. Ex. *Kharif* rice, *kharif* maize, *rabi* maize, summer pulse etc.

5. Based on climatic condition

1) Tropical crop : Coconut, sugarcane
2) Sub-tropical crop : Rice, cotton
3) Temperate crop : Wheat, barley
4) Polar crop : All pines, pasture grasses

SOILS

Soil is defined as the thin layer of earth's crust made up of disintegrated and decomposed rocks, complex mineral compound, organic matter, water/air and living organism like bacteria, fungi, insects and worms and serves as the natural medium of growth of plants.

It provides nutrients, moisture, anchorage (support) and provides air to root system. There are different soil groups found in varied regions of India. Each group differs from other in physical and chemical properties. The variation in behaviour is mainly due to the nature of the parent material from which the soils are formed. Parent materials are Igneous rocks, sedimentary rocks and metamorphic rocks. Physical properties like structure, texture, colour, water holding capacity, depth etc. are to be noted. Chemical properties like the presence of various plant elements, pH, EC, CEC, acidic or alkaline, etc. are considered.

Classification based on soil taxonomy

Order : *Entisols* Suborder : Fluvents
Great Group : Torrifluvents Subgroup : Typic Torrifluvents
Family : Fine-loamy, mixed, superactive, calcareous, Typic Torrifluvents
Series : Jocity, Youngston.

Major soils of India

1. Alluvial soil (*Entisols, Inceptisols and Alfisol)*
2. Black soil (*Vertisol*)
3. Red soil (*Alfisol*)
4. Laterite soil (*Ultisol*)
5. Desert soil (*Aridisol*)
6. Forest soil and hill soil, peat and marshy soils
7. Problem soils (saline, alkali, acid)

1. Alluvial soil or Indo-Gangetic Alluvium

This is the most extensive soil found in India. Out of total area of India, 48.0 m.ha comes under river alluvium. These soils include deltaic alluvium, calcareous alluvium and coastal alluvium. Alluvial soils are formed by transportation in streams and rivers and are deposited in flood plains or along the coastal belts. Newly formed alluvium may not have distinct soil horizons while older alluvium may have soil horizons. They occur in the basins of Indus, Ganges, Brahmaputra, Godavari, Krishna, Cauvery and Tambiraparani deltas spread in U.P., Bihar, West Bengal, Gujarat, Punjab, Rajasthan, Andhra Predesh, Tamil Nadu.

Newer alluvium is called as *Khadar*, is sandy, light colour and less *Kankar* nodules. Older alluvium is called as *Bhangar*, full of clay, dark colour and more *Kankar* nodules. Alluvial soils of high altitude are acidic in nature and plains are neutral to alkaline. Alluvial soils of plains are medium in phosphorous content and high in potassium content. Generally, alluvial soils are rich in nutrients and are fertile and they support good crop growth with plenty of water. Many crops including vegetable are cultivated in river alluvium. Crops like rice, wheat, cotton, maize, sugarcane, vegetables, jute, oil seeds, millets, pulses and fruits are cultivated in these soil.

2. Black soil

Dark-grey in colour due to clay-humus complex. Area around 32.0 m.ha is under this soil. This soil is also called black cotton soil, mixing of soil along the entire column with *Montmorillonite* clay. Cotton grows very well with water available in soil. Black soil holds more moisture and available for a long time. Found in Maharashtra, Madhya Pradesh, South Orissa, South and Coastal Andhra Pradesh, North Karnataka and parts of Tamil Nadu. Black soil contains high proportion of clay (30-40%), so, the water holding capacity is high. Typical characteristics of this black soil are swelling (during wet period) and shrinkage (dry period). While dry, it forms very deep cracks of more than 30-45 cm. In Kovilpatti (Tamil Nadu) areas the cracks may extend to 2 to 3 m with a width of 1 to 6 cm. Field preparation takes longer time compared to other soil. Only after secondary tillage, the soil is suited for crop production. The soils are fine grained contain high proportion of Calcium and Magnesium carbonates. They are poor in N, medium in P and medium to high in K (Characteristic feature of typical Indian soil).

In Tamil Nadu Black soils have high pH (8.5 to 9) and are rich in lime (5-7%), have low permeability. The soils are with more cation exchange capacity (40-60 m.e./100 g). Crops grown in this soil are cotton, bengal gram, mustard, millets, pulses, oil seeds (sunflower, safflower) are commonly grown in this soil. Most of the soils come under rainfed areas.

3. Red soil

Based on the colour (due to presence of ferric oxides) it is called as red soil. Around 30 m.ha are found in India. They are formed from granites and other metamorphic rocks. Mostly found in semi-arid areas and the colour varies from red to yellow. The soil is light textured, with *Kaolinite* type of clay. Well drained with moderate permeability. Low cation exchange capacity and low water holding capacity. Red soil is present in Gujarat, Tamil Nadu, Karnataka, Andhra Pradesh, North and East of Arunachal Pradesh, Madhya Pradesh, Parts of Bihar and Uttar Pradesh. They are shallow in depth because they are degraded or drained soil. Lesser clay and more sandy than *Vertisol*. Red soil is always in acidic nature. Highly suitable for groundnut crop cultivation. Crops like millets, pulses, oil seeds (ground nut, gingelly, castor) and tuber crops like cassava are commonly cultivated.

4. Laterites and Lateritic soil

Laterite soils are formed due to the process of laterisation. i.e., leaching of all cations leaving Fe and Al oxides. Mostly found in hills and foothill areas. This soil is formed under high intensive down pour of rainfall. It is modified form of red soil, clay content is minimum. Rich in organic matter content and rich in fertility and medium water holding capacity. They become very hard when there is no water. The cohesive nature is high. Acid loving crops (Plantation crops) and fruits (pineapple, avacado) are more cultivated. Tea, rubber, pepper, spices are cultivated. At lower elevation places, rice is grown.

5. Desert soil

Found in desert regions of Rajasthan (Thar desert), parts of Haryana and Punjab of India. More sand is found and sand dunes are common. Clay content is < 8% only. Poor fertility, poor water holding capacity and susceptible to soil erosion. Presence of sodic salts (high Na content) leads to alkalinity. Crops like date palm, cucumber, millets are cultivated (countries like Saudi Arabia, UAE, Jordan, Sudan etc).

6. Peaty and Organic soil

These soils are very rich in organic matter. Found in Kerala, coastal regions of West Bengal, Orissa, South and East coast of Tamil Nadu. Deposition of organic matter by the elevated soil. Peaty and organic soil is not suitable for majority of crops. Rice is mostly cultivated in coastal area in rainy season.

7. Problem soil

Saline soils: Contain excess amounts of neutral soluble salts dominated by chlorides and sulphates of Na, Ca and Mg affects plant growth. White encrustation of salts and hence called white alkali. These soils are characterized by, EC: $4dSm^{-1}$ at 25°C, ESP: < 15; pH; < 8.5. This soil needs leaching and drainage before cropping for amelioration.

i) High salt tolerant: *Sesbania*, Rice, sugarcane, oats, berseem, lucerne, indian clover & barley.

ii) Medium salt tolerant: Castor, cotton, sorghum, pearl millet, maize, mustard & wheat.

iii) Low salt tolerant: Pulses, peas, *Sunnhemp*, gram, linseed and sesame.

Sodic / Alkali soils: High content of carbonates and bicarbonates of Na. Hence, they are with high exchangeable sodium percentage (ESP) with dark encrustation, hence called as black alkali. These soils are rich in $NaHCO_3$ and characterized by pH: > 8.5; EC : < $4dSm^{-1}$; ESP : > 15. Use gypsum ($CaSO_4$, $2H_2O$) as amendment for reclamation of sodic alkali soils. Iron pyrites (FeS_2), bulky organic manures (especially green manure) and crop residues which produces weak organic acids.

i) Tolerant crops: Karnal / rhodes / para/ bermuda grass, rice and sugar beet.

ii) Semi–tolerant: Wheat, barley, oats, berseem and sugarcane.

iii) Sensitive: Cowpea, gram, groundnut, lentil, peas and maize.

Acid soils: These are low pH with high amounts of exchangeable H^+ and Al_3. Occur in regions with high rainfall. Significant amount of partly decomposed organic matter exist. Have low CEC and high base saturation. Liming and judicious use of fertilizers are the management measures suggested. Suitable crops: Acedophytes (like potato).

Comparison of three types of soils

Parameters	Saline soil	Saline alkali	Alkali soil
EC (dS/m)	>4	>4	<4
ESP (%)	<15	>15	>15
pH	<8.5	<8.5	>8.5

Soils of Tamil Nadu

Type of Soil	**Areas in Tamil Nadu**
Red loam (79.8 L. ha & 61.7%)	Parts of Kancheepuram, Cuddalore, Salem, Dharmapuri, Coimbatore, Tiruchirappalli, Thanjavur, Ramanathapuram, Madurai, Tirunelveli, Sivagangai, Thoothukudi, Virudhunagar, Dindigul and The Nilgiris Districts.
Laterite soil (3.8 L.ha & 2.9%)	Parts of The Nilgiris District
Black soil (15.0 L. ha & 11.6%)	Parts of Kancheepuram, Cuddalore, Vellore, Thiruvannamalai, Salem, Dharmapuri, Madurai, Ramanathapuram, Tirunelveli, Sivagangai, Thoothukudi, The Nilgiris, Virudhunagar and Dindigul Districts.
Sandy coastal alluvium (9.8 L. ha & 7.6%)	On the Coasts in the districts of Ramanathapuram, Thanjavur, Nagapattinam, Cuddalore, Kancheepuram and Kanyakumari
River alluvium (21.0 L. ha & 16.2%)	All river deltaic areas (Cauvery, Vaigai, Tambiraparani)

Source: Department of Economics and Statistics, Chennai

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

CROP GROWTH

INTERNAL FACTORS
(Genetic or heredity)

EXTERNAL FACTORS
(Environmental)
A. Climatic
B. Edaphic
C. Biotic
D. Physiographic
E. Socio-economic

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

3. Atmospheric Humidity (Relative Humidity - RH)

- Water is present in the atmosphere in the form of invisible water vapour, normally known as humidity. Relative humidity is ratio between the amount of moisture present in the air to the saturation capacity of the air at a particular temperature.
- If relative humidity is 100% it means that the entire space is filled with water and there is no soil evaporation and plant transpiration.
- Relative humidity influences the water requirement of crops
- Relative humidity of 40-60% is suitable for most of the crop plants.
- Very few crops can perform well when relative humidity is 80% and above.
- When relative humidity is high there is chance for the outbreak of pest and disease.

4. Solar radiation (without which life will not exist)

- From germination to harvest and even post harvest crops are affected by solar radiation.
- Biomass production by photosynthetic processes requires light.
- All physical process taking place in the soil, plant and environment are dependent on light
- Solar radiation controls distribution of temperature and there by distribution of crops in a region.
- Visible radiation is very important in photosynthetic mechanism of plants. Photosynthetically Active Radiation (PAR - 0.4 – 0.7µ) is essential for production of carbohydrates and ultimately biomass.

0.4 to 0.5 µ - Blue – violet – Active
0.5 to 0.6 µ - Orange – red - Active
0.5 to 0.6 µ - Green –yellow – low active

- Photoperiodism is a response of plant to day length

Short day – Day length is <12 hours (Rice, Sunflower and cotton), long day – Day length is > 12 hours (Barley, oat, carrot and cabbage), day neutral – There is no or less influence on day length (Tomato and maize).

- Phototropism — Response of plants to light direction. Eg. Sunflower
- Photosensitive – Season bound varieties depends on quantity of light received

5. Wind velocity

- The basic function of wind is to carry moisture (precipitation) and heat.
- The moving wind not only supplies moisture and heat, also supplies fresh CO_2 for the photosynthesis.
- Wind movement for 4 – 6 km/hour is suitable for more crops.
- When wind speed is enormous then there is mechanical damage of the crops (i.e.) it removes leaves and twigs and damages crops like banana, sugarcane
- Wind dispersal of pollen and seeds is natural and necessary for certain crops.
- Causes soil erosion.
- Helps in cleaning produce to farmers.
- Increases evaporation.
- Spread of pest and diseases.

6. Atmospheric gases on plant growth

- CO_2 – 0.03%, O_2 - 20.95%, N_2 - 78.09%, Argon - 0.93%, Others - 0.02%.
- CO_2 is important for Photosynthesis, CO_2 taken by the plants by diffusion process from leaves through stomata
- CO_2 is returned to atmosphere during decomposition of organic materials, all farm wastes and by respiration
- O_2 is important for respiration of both plants and animals while it is released by plants during Photosynthesis
- Nitrogen is one of the important major plant nutrient, Atmospheric N is fixed in the soil by lightning, rainfall and N fixing microbes in pulses crops and available to plants
- Certain gases like SO_2, CO, CH_4, HF released to atmosphere are toxic to plants

B. EDAPHIC FACTORS (soil)

Plants grown in land completely depend on soil on which they grow. The soil factors that affect crop growth are

1. Soil moisture
2. Soil air
3. Soil temperature
4. Soil mineral matter
5. Soil organic matter
6. Soil organisms
7. Soil reactions

1. Soil moisture

- Water is a principal constituent of growing plant which it extracts from soil
- Water is essential for photosynthesis
- The moisture range between field capacity and permanent wilting point is available to plants.
- Available moisture will be more in clay soil than sandy soil
- Soil water helps in chemical and biological activities of soil including mineralization
- It influences the soil environment Eg. it moderates the soil temperature from extremes

- Nutrient availability and mobility increases with increase in soil moisture content.

2. Soil air

- Aeration of soil is absolutely essential for the absorption of water by roots
- Germination is inhibited in the absence of oxygen
- O_2 is required for respiration of roots and micro organisms.
- Soil air is essential for nutrient availability of the soil by breaking down insoluble mineral to soluble salts
- For proper decomposition of organic matter
- Potato, tobacco, cotton linseed, tea and legumes need higher O_2 in soil air
- Rice requires low level of O_2 and can tolerate water logged (absence of O2) condition.

3. Soil temperature

- It affects the physical and chemical processes going on in the soil.
- It influences the rate of absorption of water and solutes (nutrients)
- It affects the germination of seeds and growth rate of underground portions of the crops like tapioca, sweet potato.
- Soil temperature controls the microbial activity and processes involved in the nutrient availability
- Cold soils are not conducive for rapid growth of most of agricultural crops

4. Soil mineral matter

- The mineral content of soil is derived from the weathering of rocks and minerals as particles of different sizes.
- These are the sources of plant nutrients

  eg; Ca, Mg, S, Mn, Fe, K etc

5. Soil Organic matter

- It supplies all the major, minor and micro nutrients to crops
- It improves the texture of the soil
- It increases the water holding capacity of the soil,
- It is a source of food for most microorganisms
- Organic acids released during decomposition of organic matter enables mineralisation process thus releasing unavailable plant nutrients

6. Soil organisms:

- The raw organic matter in the soil is decomposed by different micro organisms which in turn releases the plant nutrients
- Atmospheric nitrogen is fixed by microbes in the soil and is available to crop plants through symbiotic (*Rhizobium*) or non-symbiotic (*Azospirillum*) association

7. Soil reaction (pH)

- Soil reaction is the pH (hydrogen ion concentration) of the soil.
- Soil pH affects crop growth and neutral soils with pH 7.0 are best for growth of most of the crops
- Soils may be acidic (<7.0), neutral (=7.0), saline and alkaline (>7.0)
- Soils with low pH is injurious to plants due high toxicity of Fe and Al.
- Low pH also interferes with availability of other plant nutrients.

C. BIOTIC FACTORS

Beneficial and harmful effects caused by other biological organism (plants and animals) on the crop plants

1. Plants

- Competitive and complimentary nature among field crops when grown together
- Competition between plants occurs when there is demand for nutrients, moisture and sunlight particularly when they are in short supply or when plants are closely spaced

- When different crops of cereals and legumes are grown together, mutual benefit results in higher yield (synergistic effect)
- Competition between weed and crop plants as parasites eg: *Striga* parasite weed on sugarcane crop

2. Animals

- Soil fauna like protozoa, nematode, snails, and insects help in organic matter decomposition, while using organic matter for their living
- Insects and nematodes cause damage to crop yield and considered as harmful organisms.
- Honey bees and wasps help in cross pollination and increases yield and considered as beneficial organisms
- Burrowing earthworm facilitates aeration and drainage of the soil as ingestion of organic and mineral matter by earthworm results in constant mixing of these materials in the soils.
- Large animals cause damage to crop plants by grazing (cattle, goats etc)

D. Physiographic factors:

- Topography is the nature of surface earth (leveled or sloppy) is known as topography. Topographic factors affect the crop growth indirectly.
- Altitude – increase in altitude cause a decrease in temperature and increase in precipitation and wind velocity (hills and plains)
- Steepness of slope: it results in run off of rain water and loss of nutrient rich top soil
- Exposure to light and wind: a mountain slope exposed to low intensity of light and strong dry winds may results in poor crop yields (coastal areas and interior pockets)

E. Socio-economic factors

- Society inclination to farming and members available for cultivation
- Appropriate choice of crops by human beings to satisfy the food and fodder requirement of farm household.
- Breeding varieties by human invention for increased yield or pest & disease resistance
- The economic condition of the farmers greatly decides the input/ resource mobilizing ability (marginal, small, medium and large farmers)

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.

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.

<u>2. Off-season tillage:</u> 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.

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.

<u>Main field preparation:</u>

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.

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 plain surface. The seeds are dibbled at 2/3rd from top or 1/3rd at 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.

Advantages of line sowing are, (i) uniform population, (ii) better germination, (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 seed rate
4.	Mechanization is possible, e.g. weeding, harvesting	Not possible
5.	Uniform utilization of resources (land, water, light, nutrient, etc.)	Resource utilization is un-uniform

3. Sowing behind the plough

Sowing behind the plough is done by manual 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.

4. Drill sowing (or) Drilling

Drilling is the practice of dropping seeds in a definite depth covered with soil and compacted. In this method, sowing implements are used for placing the seeds into the soil. Both animal drawn Gorus and power operated (seed drills) implements are available. Seeds are drilled continuously or at regular intervals in rows. In this method, depth of sowing can be maintained and fertilizer can also be applied simultaneously. It is possible to take up sowing of inter crops also. It requires more time, energy and cost, but maintains uniform population per unit area. Seeds are placed at uniform depth, covered and compacted.

5. Transplanting

This method of planting has two components, a. nursery and b. transplanting. In nursery, young seedlings are protected more effectively in a short period and in a smaller area. Management is easy and economical.

Advantages

- Can ensure optimum plant population
- Sowing of main field duration, i.e., management in the main field is reduced
- Crop intensification is possible under transplanting

Disadvantages

- Nursery raising is expensive
- Transplanting is another laborious and expensive method

Age of seedlings is 1/4th of the total duration of the crop. If the total duration is 16 weeks, four week period (1 month) is under nursery beds. Nursery age is not very rigid, e.g., thumb rule – 3 months crop – nursery duration 3 weeks, minimum 4 months – 4 weeks minimum period; 5 months

– 5 weeks. After the nursery period, seedlings are pulled out and transplanted. This is done on the main field after thorough field preparation or optimum tilth. The seedlings are dibbled in lines or in random. Closer spaced crops are mostly raised in random method even after nursery, Ex. rice and finger millet. For vegetables, desired spacing is required during transplanting. Transplanting shock is a period after transplanting, the seedlings show no growth. This is mostly due to the change in the environment between root and the soil. The newly planted seedlings should adjust with new environment. It is for a period of 5-7 days depending upon season, crop, variety, etc. At higher temperature, dehydration is possible and leaves dried out. Area required for nursery normally is $1/10^{th}$ of the total area.

GERMINATION

- Germination is a protrusion of radicle or seedling emergence.
- Germination results in the rupture of the seed coat and emergence of seedling from embryonic axis.

Factors affecting seed germination

1. Soil: Soil type, texture, structure and microorganisms greatly influence the seed germination.
2. Moisture: When the seeds do not get required moisture in the soil, the viability is lost. When the moisture is excess after germination, it will lead to rotting of the sprouts.
3. Temperature: When it is above and below the optimum temperature, the germination rate will be affected.
4. Light: The most effective wavelength for promoting germination is red (662 nm) and 730 nm inhibits germination.
5. Soil condition: a. Tilth is the most important soil factor influences on germination of seed. Small seeds require fine tilth whereas, moderate and larger seeds requires medium and coarse tilth soils, respectively.

   b. Depth of sowing: The seeds should be placed at optimum depth. When the seeds are placed at deeper layers they have to spend more energy for germination. When it is placed on soil surface, it will be taken away by birds/worked away. The thumb rule is to sow seeds to a depth of approximately 3 to 4 times diameter of the seed. The optimum depth of sowing for most of the field crops ranged between 3 and 5 cm depth. The seeds sown should be protected from rodents or birds before germination by employing labourers to scare the birds at least for three days after sowing.

CROP STAND ESTABLISHMENT

Good crop establishment is one of the most important features in better crop production. The better crop establishment is in turn expressed as optimum plant population in fields. Number of plants per unit area in the cropped field is called as plant population.

Optimum plant population

It is the number of plants required to produce maximum output or biomass per unit area. Any increase beyond this stage results in either no increase or reduction in biomass.

Importance of plant population

- Yield of any crop depends on final plant population.
- The plant population depends on germination percentage and survival rate in the field.
- Under rain fed conditions, high plant population will deplete the soil moisture before maturity, where as low plant population will leave the soil moisture unutilized.
- When soil moisture and nutrients are not limited high plant population is necessary to utilize the other growth factors like solar radiation efficiently.
- Under low plant population, individual plant yield will be more due to wide spacing.

- Under high plant population, individual plant yield will be low due to narrow spacing leading to competition between plants.
- Yield per plant decreases gradually as plant population per unit area is increased, but yield per unit area increases up to certain level of population. That level of plant population is called as optimum population.
- So, to get maximum yield per unit area, optimum plant population is necessary. So the optimum plant population for each crop should be identified.

Factors affecting plant population

A. Genetic Factors

1. Size of the plant

- The volume occupied by the plant at the time of flowering decides the spacing of the crop.
- Plants of red gram, cotton, sugarcane etc. occupy larger volume of space in the field compared to rice and wheat.
- Even the varieties of the same crop differ in size of the plant.

2. Elasticity of the plant

- Variation in size of the plant between minimum size of the plant that can produce some economic yield to the maximum size of the plant that can reach under unlimited space and resources is the elasticity of the plant.
- The optimum plant population range is high in indeterminate plants. Ex. Redgram – 55,000 to1,33,000 plants/ha.
- The elasticity is due to tillering and branching habit of the plants.
- For determinate plants like pearl millet, sorghum elasticity range is less.
- For indeterminate plants like cotton and Redgram, more branches will be produced by the crop.

3. Foraging area or soil cover

- Crop should cover the soil as early as possible so as to intercept maximum sunlight.
- Higher the intercepted radiation more will be the dry matter produced.
- Close spaced crops intercept more solar radiation than wide spaced crops.

4. Dry matter partitioning

- Dry matter production is related to amount of solar radiation intercepted by the canopy which depends on plant density.
- As the plant density increases, the canopy expands more rapidly, more radiation is intercepted and more dry matter is produced.

5. Crop and variety

Depending on the crops and varieties, the plant population varies.

Rice :	Short duration	-	6,66,666 plants/ha (15 cm x 10 cm)
	Medium	-	5,00,000 plants/ha (20 cm x 10 cm)
	Long	-	3,33,000 plants/ha (20 cm x 15 cm)
Cotton :	Medium	-	55,555 plants/ha (60 cm x 30 cm)
	Long	-	44444 plants/ha (75 cm x 30 cm)
	Hybrids	-	18,518 plants/ha (120 cm x 45 cm)
Maize :	Varieties	-	83,333 plants/ha (60 x 20 cm)
	Hybrids	-	47,620 plants/ha (60 x 35 cm)

B. Environmental factors

1. Time of sowing

- The crop is subjected to various weather conditions when sown at different periods.

- Among weather factors, day length and temperature influence much on the plant population. As low temperature retards growth, high plant population is required to cover the soil.

2. Rainfall / irrigation

1. Plant population has to be less under rainfed than irrigated condition.
2. Under more plant densities, more water is lost through transpiration.
3. Under adequate rainfall / irrigation, high plant population is recommended.

3. Fertilizer application

1. Higher plant population is necessary to fully utilize higher level of nutrients in the soil to realize higher yield.
2. Nutrient uptake increases at optimum plant population.
3. High population under low fertility soils leads to nutrient deficiency symptoms leading low yield.

4. Seed rate

- Quantity of seed sown/unit area, viability and establishment rate decides the plant population. Under broadcasting the seed rate is higher when compared with line sowing/transplanting, Ex. Rice.

  Direct sowing - 100 kg/ha; Line sowing - 60 kg/ha; Transplanting - 40 kg/ha.

PLANT GEOMETRY

The arrangement of the plants in different rows and columns in an area to utilize the natural resources efficiently is called crop geometry. It is otherwise area occupied by a single plant Ex.. Rice – 20 cm x 15 cm. This is very essential to utilize the resources like light, water, nutrient and space. Different geometries are available for crop production

Different crop geometries are available for crop production

1) Random plant geometry

Random plant geometry results due to broadcasting method of sowing and no equal space is maintained. Resources are either under utilized or over exploited.

2) Square plant geometry

The plants are sown at equal distances on either side. Mostly perennial crops, tree crops follow square method of cultivation. Ex. Coconut – 7.5 x 7.5 m; banana – 1.8 x 1.8 m. But, due to scientific invention, the square geometry concept is expanded to close spaced field crops like rice too.

Advantages

Light is uniformly available, movement of wind is not blocked and mechanization can be possible.

3) Rectangular method of sowing

There are rows and columns, the row spacing are wider than the spacing between plants.

The different types exist in rectangular method are,

a) Solid row: Each row will have no proper spacing between the plants. This is followed only for annual crops which have tillering pattern. There is definite row arrangement but no column arrangement, Ex. Wheat.

b) Paired row arrangement: It is also a rectangular arrangement. It a crop requires 60 cm x 30 cm spacing and if paired row is to be adopted the spacing is altered to 90 cm instead of 60 cm in order to accommodate an intercrop. The base population is kept constant.

c) Skip row: A row of planting is skipped and hence there is a reduction in population. This reduction is compensated by planting an intercrop; practiced in rainfed or dryland agriculture.

d) Triangular method of planting: It is recommended for wide spaced crops like coconut, mango, etc. The number of plants per unit area is more in this system.

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

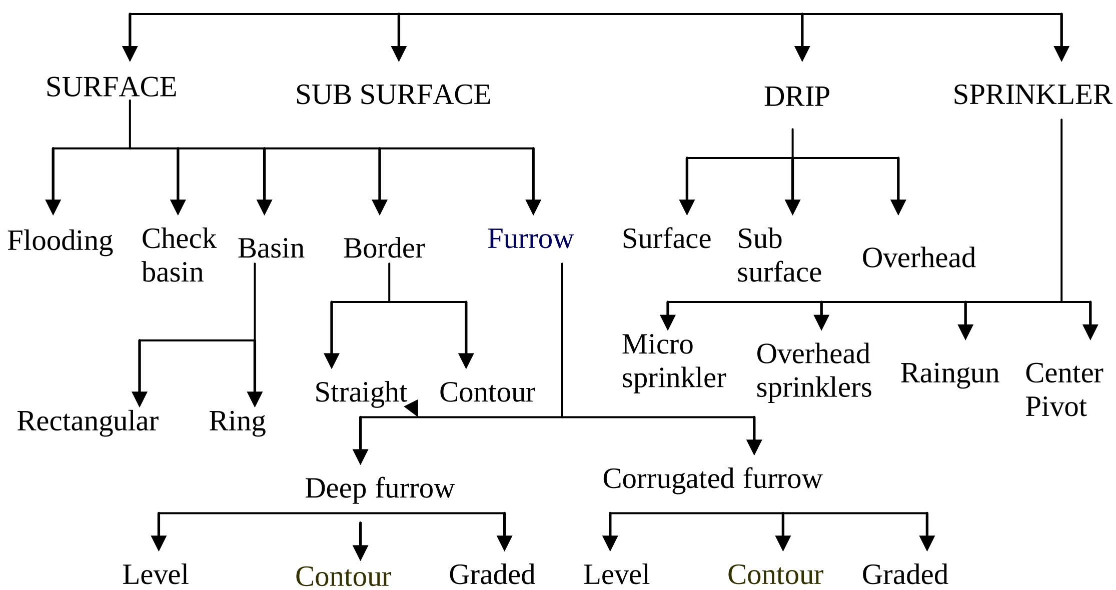
The land is divided into number of long parallel strips called borders. These borders are separated by low ridges. The border strip has a uniform gentle slope in the direction of irrigation. Each strip is irrigated independently by turning the water in the upper end. The water spreads and flows down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



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

4. Drill Sowing (or) Drilling

Drilling is the practice of dropping seeds in a definite depth covered with soil and compacted. In this method, sowing implements are used for placing the seeds into the soil. Both animal drawn gorrus and power operated (seed drills) implements are available. Seeds are drilled continuously or at regular intervals in rows. In this method, depth of sowing can be maintained and fertilizer can also be applied simultaneously. It is possible to take up sowing of inter crops also. It requires more time, energy and cost, but maintains uniform population per unit area Seeds are placed at uniform depth, covered and compacted

5) Nursery Transplanting

In nursery, young seedlings are protected more effectively in a short period and in a smaller area. Management is essential.

Advantages

i) Can ensure optimum plant population

ii) Sowing of main field duration, i.e., management in the main field is reduced

iii) Crop intensification is possible under transplanting

Disadvantages

i) Nursery raising is expensive

ii) Transplanting is another laborious and expensive method

Age – 1/4th of the total duration is on the nursery beds. If the total duration is 16 weeks, four week period (1 month) is under nursery beds. Nursery age is not very rigid, e.g., thumb rule – 3 months crop – nursery duration 3 weeks, minimum 4 months – 4 weeks minimum period; 5 months – 5 weeks. After the nursery period, seedlings are pulled out and transplanted. This is done on the main field after thorough field preparation or optimum tilth. The seedlings are dibbled in lines or in random. Closer spaced crops are mostly raised in random method even after nursery, e.g. rice, ragi. For vegetables, desired spacing is required during transplanting. Transplanting shock is a period after transplanting, the seedlings show no growth. This is mostly due to the change in the environment between root and the soil. The newly planted seedlings should adjust with new environment. It is for a period of 5 – 7 days depending upon season, crop, variety, etc. At higher temperature – dehydration – leaves dry out. Area: normally 1/10th of the total area is required for nursery.

Plant Population or Plant Density

Number of plants per unit area in the cropped field is the plant population.

Optimum plant population

1. Optimum plant population – It is the number of plants required to produce maximum output or biomass per unit area.
2. Any increase beyond this stage results in either no increase or reduction in biomass.

Crop Geometry

The arrangement of the plants in different rows and columns in an area to efficiently utilize the natural resources is called crop geometry.It is otherwise area occupied by a single plant e.g. rice – 20 cm x 15 cm. This is very essential to utilize the resources like light, water, nutrient and space.Different geometries are available for crop production

Importance of plant population / crop geometry

1. Yield of any crop depends on final plant population
2. The plant population depends on germination percentage and survival rate in the field
3. Under rain fed conditions, high plant population will deplete the soil moisture before maturity, where as low plant population will leave the soil moisture unutilized
4. When soil moisture and nutrients are not limited high plant population is necessary to utilize the other growth factors like solar radiation efficiently
5. Under low plant population individual plant yield will be more due to wide spacing.
6. Under high plant population individual plant yield will be low due to narrow spacing leading to competition between plants.
7. Yield per plant decreases gradually as plant population per unit area is increased, but yield per unit area increases upto certain level of population
8. That level of plant population is called as optimum population
9. So to get maximum yield per unit area, optimum plant population is necessary. So the optimum plant population for each crop should be identified.

Factors affecting plant population

Genetic Factors

1. Size of the plant 2. Elasticity of the plant 3.Foraging area or soil cover

4. Dry matter partitioning

Environmental factors

1. Time of sowing 2. Rainfall / Irrigation. 3.Fertilizer application

4. Seed rate

1. Size of the plant

1. The volume occupied by the plant at the time of flowering decides the spacing of the crop
2. Plants of red gram, cotton, sugarcane etc occupy larger volume of space in the field compared to rice, wheat, ragi
3. Even the varieties of the same crop differ in size of the plant

2. Elasticity of the plant

1. Variation in size of the plant between minimum size of the plant that can produce some economic yield to the maximum size of the plant that can reach under unlimited space and resources is the elasticity of the plant.
2. The optimum plant population range is high in indeterminate plants

   Eg : Opt. population range for redgram is 55000-133, 000 plants/ha
3. The elasticity is due to tillering and branching habit of the plants
4. For determinate plants like bajra, sorghum elasticity range is less
5. For indeterminate plants like cotton and redgram more branches will be produced the crop

3. Foraging area or soil cover

1. should cover the soil as early as possible so as to intercept maximum sunlight
2. Higher the intercepted radiation more will be the dry matter produced
3. Close spaced crops intercept more Solar radiation than wide spaced crops

4. Dry matter partitioning

1. Dry matter production is related to amount of solar radiation intercepted by the canopy which depends on plant density
2. As the plant density increases the canopy expands more rapidly, more radiation is intercepted and more dry matter is produced.

5. Crop and variety

Rice :	Short duration	-	15 cm x 10 cm- 6,66,666 pl/ha
	Medium	-	20 cm x 10 cm-5,00,000 pl/ha
	Long	-	20 cm x 15 cm-3,33,000 pl/ha
Cotton :	Medium	-	60 cm x 30 cm
	Long	-	75 cm x 30 cm
	Hybrids	-	120 cm x 45 cm
Maize :	60 x 20 cm (varieties)		
	60 x 35 cm (hybrids)		

Environmental factors

1. Time of sowing
   1. The crop is subjected to various weather conditions when sown at different periods.
   2. Among weather factors, day length and temperature influence the plant population. As low temperature retards growth, high plant population is required to cover the soil

2. Rainfall / irrigation

1. Plant population has to be less under rainfed than irrigated condition
2. Under more plant densities, more water is lost through transpiration
3. Under adequate rainfall / irrigation, high plant population is recommended.

3. Fertilizer application

1. Higher plant population is necessary to fully utilize higher level of nutrients in the soil to realize higher yield.
2. Nutrient uptake increases with in plant population
3. High population under low fertility soil leads to nutrient deficiency symptoms leading low yield

4. Seed rate

1. Quantity of seed sown/unit area, viability and establishment rate decides the plant population Under broadcasting the seed rate is higher when compared with line sowing/transplanting, e.g. for rice

   Direct sowing - 100 kg/ha

   Line sowing - 60 kg/ha

   Transplanting - 40 kg/ha

Different crop geometries are available for crop production

1) Broadcasting

Results in random geometry, no equal space is maintained, resources are either under exploited or over exploited.

2) Square method or square geometry

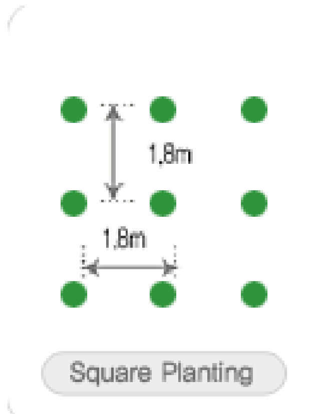
The plants are sown at equal distances on either side. Mostly perennial crops, tree crops follow square method of cultivation.

Advantages

i) Light is uniformly available,

ii) Movement of wind is not blocked and

iii) Mechanization can be possible.



3) Rectangular method of sowing

There are rows and columns, the row spacing are wider than the spacing between plants. The different types exist in rectangular method

a) Solid row – Each row will have no proper spacing between the plants. This is followed only for annual crops which have tillering pattern. There is definite row arrangement but no column arrangement, e.g., wheat.

b) Paired row arrangement – It is also a rectangular arrangement. It a crop requires 60 cm x 300 m spacing and if paired row is to be adopted the spacing is altered to 90 cm instead of 60 cm in order to accommodate an intercrop. The base population is kept constant.

SPRING MAIZE INTER-CROP IN PAIRED ROW PLANTING

c) Skip row – A row of planting is skipped and hence there is a reduction in population. This reduction is compensated by planting an intercrop; practiced in rainfed or dryland agriculture.

Conventional planting on the left, compared with plant1 – skip1 on the right

d) Triangular method of planting - It is recommended for wide spaced crops like coconut, mango, etc. The number of plants per unit area is more in this system.

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

Difference between rainfed and irrigated farming

	Rainfed farming	**Irrigated farming**
1	In a certain part of the year crop is grown where rainfall received	Through out the year depending upon the water availability
2	Crops/crop varieties having drought tolerance or less water requirement are used	According to the need, crops or their varieties are selected
3	Duration of crops depends on the rainfall duration/ growing period most of the times short duration (LGP)	Depending upon the need
4	Mixed cropping is beneficial	Generally pure cropping is done
5	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
6	The field is ploughed to deep to increase infiltration of rains	No need for deep ploughing to conserve soil moisture
7	Land is prepared immediately after rainfall	Land is prepared according to optimum time of sowing
8	Risk of crop failure is expected due to insufficient soil moisture or drought	No risk of crop failure

Improved dryland technologies

Following are the various improved techniques and practices recommended for achieving the objective of increased and stable crop production in dryland areas.

- Crop planning: Crop varieties for dryland areas should be of short duration through resistant tolerant and high yielding which can be harvested within rainfall periods and have sufficient residual moisture in soil profile for post-monsoon cropping.
- Planning for weather: Variation in yields and output of the dryland agriculture is due to the observation in weather conditions especially rainfall. An aberrant weather can be categorized in three types viz.,
    a. Delayed onset of monsoon.
    b. Long gaps or breaks in rainfall and
    c. Early cessation of rains towards the end of monsoon season.
    Farmers should make some changes in normal cropping schedule for getting some production in place of total crop failure.
- Crop substitution: Traditional crops/varieties which are inefficient utilizer of soil moisture, less responsive to production input and potentially low producers should be substituted by more efficient ones.
- Cropping systems: Increasing the cropping intensities by using the practice of intercropping and multiple cropping is the way of more efficient utilization of resources. The cropping intensity would depend on the length of growing season, which in turn depends on rainfall pattern and the soil moisture storage capacity of the soil.
- Fertilizer use: The availability of nutrients is limited in drylands due to the limiting soil moisture. Therefore, application of the fertilizers should be done in furrows below the seed. The use of fertilizers is not only helpful in providing nutrients to crop but also, helpful in efficient use of soil moisture. A proper mixture of organic and inorganic fertilizers improves moisture holding capacity of soil and increase during tolerance.
- Rain water management: Efficient rain water management can increase agricultural production from dryland areas. Application of compost and farm yard manure and raising legumes add the organic matter to the soil and increase the water holding capacity. The water, which is not retained by the soil, flows out as surface runoff. This excess runoff water can be harvested in storing dugout ponds and recycled to donar areas in the server stress during rainy season or for raising crops during winter.
- Watershed management: Watershed management is a approach to optimize the use of land, water and vegetation in a area and thus, to provide solution drought, moderate floods, prevent soil erosion, improve water availability and increase fuel, fodder and agricultural production on a sustained basis.
- Alternate Land use: All drylands are not suitable for crop production. Same lands may be suitable for range/ pasture management and for tree farming and ley farming, dryland horticulture, agro-forestry systems including alley cropping. All these systems which are alternative to crop production are called as alternate land use systems. This system helps to generate off-season employment mono-cropped dryland and also, minimizes risk, utilizes off-season rains, prevents degradation of soils and restores balance in the ecosystem. The different alternate land use systems are alley cropping, agri-horticultural systems and silvi-pastoral systems, which utilizes the resources in better way for increased and stabilized production from drylands.

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.

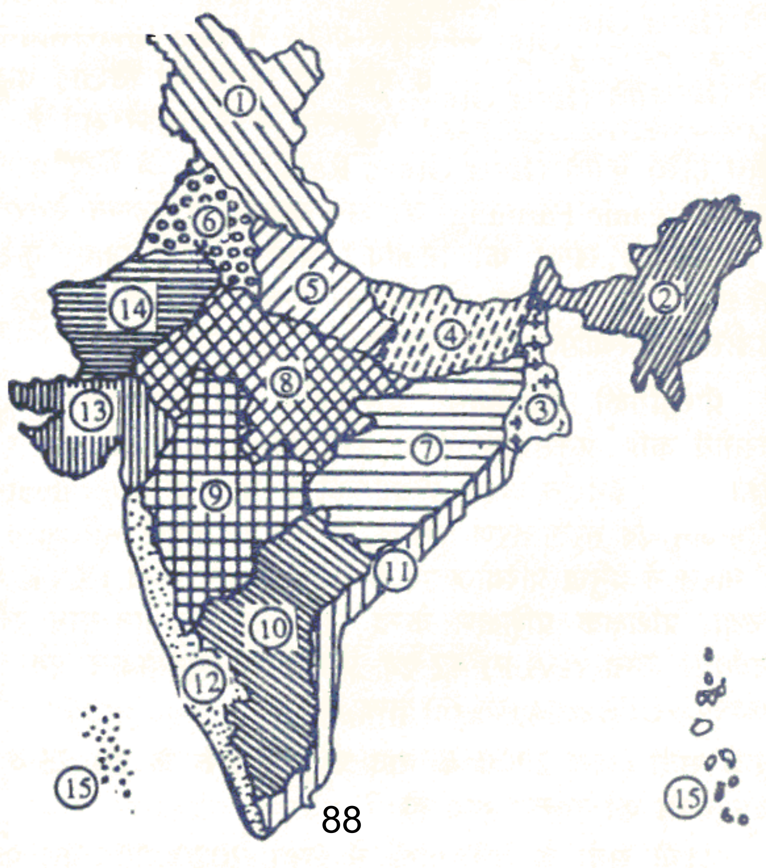
11. **East Coast Plains and Hills Region:** Orissa, Andhra Pradesh, Tamil Nadu and Pondicherry. Irrigation is through canals and tanks.

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.

AGRO METEOROLOGY

Meteorology

Greek word “Meteoro” means ‘above the earth’s surface’ (atmosphere) “logy” means ‘indicating science’. Branch of science dealing with that of atmosphere is known as meteorology. Lower atmosphere extending up to 20km from earth’s surface is where frequent physical process takes place.

Meteorology is a combination of both physics and geography Meteorology is a combination of both physics and geography. This science utilizes the principles of Physics to study the behaviour of air. It is concerned with the analysis of individual weather elements for a shorter period over a smaller area. In other words, the physical state of the atmosphere at a given place and time is referred to as “weather”. The study of weather is called ‘meteorology’. It is often quoted as the “physics of atmosphere”.

Weather: Physical state of the atmosphere at a given place and given time. Eg. Cloudy day

Climate: Long term regime of atmospheric variables of a given place or area. Eg. Cold season

Agricultural meteorology

1. A branch of applied meteorology which investigates the physical conditions of the environment of growing plants or animal organisms

2. An applied science which deals with the relationship between weather/climatic conditions and agricultural production.

3. A science concerned with the application of meteorology to the measurement and analysis of the physical environment in agricultural systems. The word ‘Agro meteorology’ is the abbreviated form of agricultural meteorology.

4. To study the interaction between meteorological and hydrological factors on the one hand and agriculture in the widest sense, including horticulture, animal husbandry and forestry on the other (WMO).

Meteorology Vs. Agricultural Meteorology

Meteorology	Agricultural meteorology
Branch of atmospheric physics	Branch of applied meteorology or a branch of agriculture as it deals with agriculture
It is a weather science	It is a product of agriculture and meteorology
It is a physical science	It is a biophysical science
It aims at weather forecasting	It aims at improving quantity and quality of crop production through meteorological skills
Weather service is the concern	Agro advisory service to the farmers is the concern based on weather forecast
It is a linking science to the society	It is a linking science to the farming community

IMPORTANCE TO CROP PRODUCTION

1. Helps in planning cropping patterns/systems.

2. Selection of sowing dates for optimum crop yields.

3. Cost effective ploughing, harrowing, weeding etc.

4. Reducing losses of applied chemicals and fertilizers.

5. Judicious irrigation to crops.

6. Efficient harvesting of all crops.

7. Reducing or eliminating outbreak of pests and diseases.

8. Efficient management of soils which are formed out of weather action.

9. Managing weather abnormalities like cyclones, heavy rainfall, floods, drought etc. This can be achieved by

(a) Protection: When rain is forecast avoid irrigation. But, when frost is forecast apply irrigation.

(b) Avoidance: Avoid fertilizer and chemical sprays when rain is forecast

(c) Mitigation: Use shelter belts against cold and heat waves.

10. Effective environmental protection.

11. Avoiding or minimizing losses due to forest fires.

FUTURE SCOPE

1. To study climatic resources of a given area for effective crop planning.

2. To evolve weather based effective farm operations.

3. To study crop weather relationships in all important crops and forecast crop yields based on agro climatic and spectral indices using remote sensing.

4. To study the relationship between weather factors and incidence of pests and diseases of various crops.

5. To delineate climatic/agro ecological/agro climatic zones for defining agro climatic analogues so as to make effective and fast transfer of technology for improving crop yields.

6. To prepare crop weather diagrams and crop weather calendars.

7. To develop crop growth simulation models for assessing/obtaining potential yields in different agro climatic zones.

8. To monitor agricultural droughts on crop-wise for effective drought management.

9. To develop weather based agro advisories to sustain crop production utilizing various types of weather forecast and seasonal climate forecast.

10. To investigate microclimatic aspects of crop canopy in order to modify them for increased crop growth

11. To study the influence of weather on soil environment on which the crop is grown

12. To investigate the influence of weather in protected environment (eg. Glass houses) for improving their design aiming at increasing crop production.

COORDINATES OF INDIA- ATMOSPHERE – COMPOSITION OF ATMOSPHERE - VERTICAL LAYERS OF ATMOSPHERE BASED ON TEMPERATURE DIFFERENCE / LAPSE RATE.

Coordinates of India

Lies between º N and º N latitude

ºE and º E longitude

Earth is elliptical in shape and has three spheres

Hydrosphere - the water portion

Lithosphere - the solid portion

Atmosphere - the gaseous portion

Atmosphere

The atmosphere is the colourless, odourless and tasteless physical mixture of gasses which surrounds earth on all sides. It is mobile, compressible and expandable. It contains huge number of solid and liquid particles called aerosol. Some gases are permanent atmospheric constituents in fixed proportions to the total gas volume. Others very from place and time to time. The lower atmosphere where the chemical composition of gas is uniform is called homosphere. At higher levels the chemical composition of air changes considerably and known as heterosphere.

Uses of atmosphere

1. Provides oxygen which is useful for respiration in crops
2. Provides carbon-dioxide to build biomass in photosynthesis.
3. Provides nitrogen which is essential for plant growth.
4. Acts as a medium for transportation of pollen.
5. Protects crops plants on earth from harmful U.V.rays.
6. Maintains warmth to plant life and
7. Provides rain to field crops as it is a source of water vapour, cloud, etc.

Composition of atmosphere

The following all the different gases that are present in percentage by volume approximately.

Nitrogen (N_2) = 78.08

Oxygen (O_2) = 20.95

Argon (Ar) =0.93 CO_2 =0.03

Neon (Ne) = 0.0018 Helium(He) =0.0005

Ozone(O_3) =0.00004 Hydrogen(H_2) =0.00006

Methane (CH_4) =0.00017

Vertical Layers of atmosphere based on temperature

On the basis of vertical temperature variation the atmosphere is divided into different spheres or layers.

A. Troposphere

1. The word “Trop” means mixing or turbulence and “sphere” means region.

2. The average height o this lower most layer of the atmosphere is about 14 km above the men sea level; at the equator it is 16 km and 7-8 km at the poles.

3. Under normal conditions the height of the troposphere changes from place to place and season to season.

4. Various types of clouds, thunderstorms, cyclone and anticyclones occur in this sphere because of the concentration of almost all the water vapour and aerosols in it. So, this layer is called as “seat of weather phenomena”.

5. The wind velocities increase with height and attain the maximum at the top of this layer.

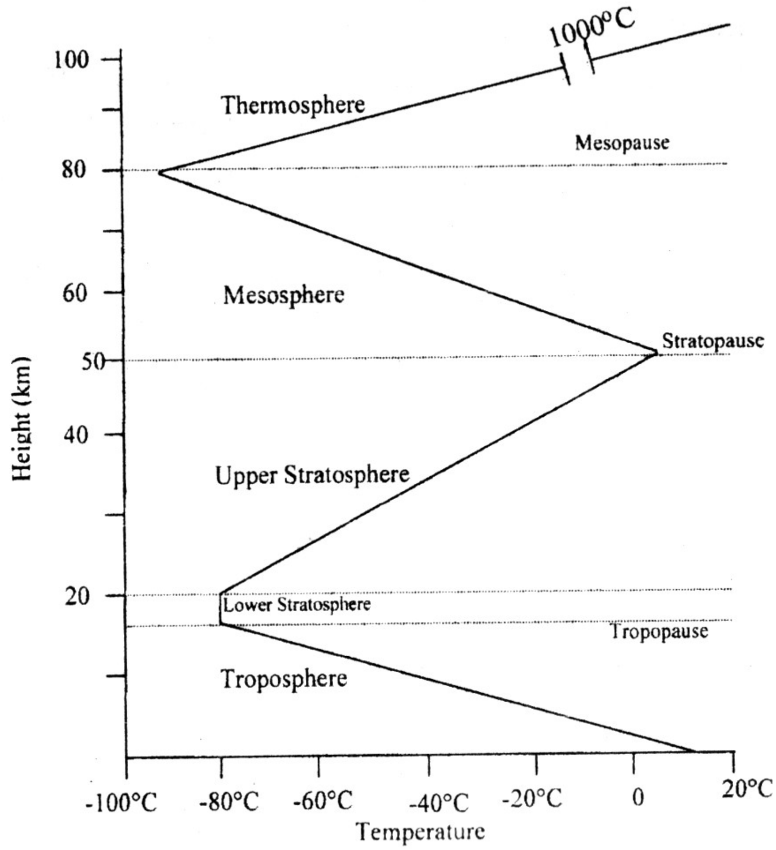
6. Another striking feature of the troposphere is that there is a decrease of temperature with increasing elevation at a mean lapse rate of about 6.5°C per km.

7. Most of the radiation received from the sun is absorbed by the earth’s surface. So, the troposphere is heated from below.

8. In this layer, about 75 per cent of total gases and most of the moisture and dust particles present.

9. A the top of the troposphere there is a shallow layer separating it from the stratosphere which is known as the “Tropopasue “.

10. The tropospause layer is thin and its height changes according to the latitudes and it is a transitional zone and distinctly characterized by no major movement of air.



TEMPERATURE BASED VERTICAL LAYERS OF ATMOSPHERE

B). Stratosphere

1). This layer exists above the tropopause (around 20 km onwards) and extends to altitudes of about 50-55 km.

2). This layer is called as "Seat of photochemical reactions"

3). The temperature remains practically constant at around 20 km and is characterized as isothermal because air is thin, clear, cold and dry near tropopause.

4). The temperature of this layer increases with height and also depends upon the troposphere because the troposphere is higher at the equator than at the poles.

5). In the upper parts of the stratosphere the temperatures are almost as high as those near the earth's surface, which is due to the fact that the ultra-violet radiation from the sun is absorbed by ozone in this region. The air density is so much less that even limited absorption of solar radiation by the atmospheric constituents notably ozone produces a temperature increase.

6). Less convection takes place in the stratosphere because it is warm at the top and cold at the bottom.

7). There is also persistence of circulation patterns and high wind speeds.

8). The upper boundary of the stratosphere is called the stratopause.

C). Mesosphere/Ozonosphere

1. There is a maximum concentration of ozone between 30 and 60 km above the surface of the earth and this layer is known at the ozonosphere.

2. A property of the ozone is that it absorbs UV rays. Had there been no layer of the ozone in the atmosphere, the ultraviolet rays might have reached the surface of the earth and no life can exist.

3. Temperature of the ozonosphere is high (warm) due to selective absorption of U.V radiation by ozone.

4. Because of the preponderance of chemical process this sphere is called as the "chemosphere"

5. In this layer the temperature increases with height at the rate of 5°C per km.

6. According to some leading scientists the ionosphere is supposed to start at a height of 80 km above the earth's surface. The layer between 50 and 80 km is called as "Mesosphere". In this layer the temperature decreases with height. The upper boundary of this layer is called the "Mesospause".

7. Mesosphere is the coldest region in the atmosphere with temperature reaching the lowest value of nearly -95°C at the mesopause (80km)

D). Thermosphere(Ionosphere)

1) The thermosphere layer lies beyond the ozonosphere (mesosphere) at a height of about 80 km above the earth's surface and extends upto 400 km.

2) The atmosphere in the ionosphere is partly ionised enriched ion zones exist in the form of distinct ionised layers. So, this layer is called as the ionosphere.

3) Above the mesosphere the temperature increases again and is in the order of 1000°C.

4) The ionosphere reflects the radio waves because of one or multiple reflections of shortwave radio beams from the inoised shells. So, long distance radio communication is possible due to this layer.

E). Exosphere.

1) The outer most layer of the earth's atmosphere is named as the exosphere and this layer lies between 400 and 1000 km.

2) At such a greater height the density of atoms in the atmosphere is extremely low.

3) Hydrogen and Helium gases predominate in this outer most region.

4) At an altitude of about 500 to 600 km the density of the atmosphere becomes so low that collisions between the natural particles become extremely rare.

Lapse rate

The decrease in air temperature with height is known as the normal / environmental lapse rate and it is 6.5°C/km.

Adiabatic lapse rate

The rate of change of temperature in an ascending or descending air mass through adiabatic process is called as adiabatic lapse rate. The thermodynamic transformation which occurs without exchange of heat between a system and its environment is known as adiabatic process. In adiabatic process, adiabatic cooling accompanies expansion, and adiabatic warming accompanies compression.

Monsoon Rainfall Variability

Indian continent receives its annual rainfall by the peculiar phenomenon known as monsoon. It consists of series of cyclones that arise in India Ocean. These travel in northeast direction and enter the Peninsular India along its west coast. The most important of these cyclones usually occur from June to September resulting in summer monsoon or southwest monsoon. This is followed by a second rainy season from October to December. A third and fourth rainy seasons occur from January to February and from March to May respectively. Of the four rainy seasons, southwest monsoon is the most important as it contribute 80 – 95% of the total rainfall of the country.

Two types of monsoon systems are a) South West Monsoon, b) North East Monsoon.

(a) South West Monsoon

Beginning of the year temperature of the Indian Peninsular rapidly rises under the increasing heat of the sun. A minimum barometric pressure is established in the interior parts of the Peninsular by the month of March. Westerly winds prevail on the west Kerala and south winds on the west of northern Circars, Orissa and Bengal. During April and May the region of high temperature is shifted to north viz., upper Sind, lower Punjab and Western Rajasthan. This area becomes the minimum barometric pressure area to which monsoon winds are directed.

The western branch of South West monsoon touches North Karnataka, Southern Maharashtra and then it make its way to Gujarat. When the South West Monsoon is fully operating on the Western India, another branch of the same is acting in the Bay of Bengal. It carries rains to Burma, Northern portions of the east coast of India, Bengal, Assam and the whole of North India in general.

b) North east Monsoon

During September end, the South West Monsoon penetrates to North Western India but stays on for a full month in Bengal. On account of the increase in barometric pressure in

Northern India, there is a shift of the barometric pressure to the South East and North Easterly winds begin to flow on the eastern coast. These changes bring on heavy and continuous rainfall to the Southern and South Eastern India.

c) Winter Rainfall

It is restricted more to Northern India and is received in the form of snow on the hills and as rains in the plains of Punjab, Rajasthan and central India. Western disturbance is a dominant factor for rainfall during these months in northwestern India.

d) Summer Rainfall

The summer Rainfall is received from March to May as local storms. It is mostly received in the South East of Peninsular and in Bengal. Western India does not generally receive these rains.

WEATHER AND CLIMATE, MICRO-CLIMATE

Weather

i) 'A state or condition of the atmosphere at a given place and at a given instant of time'.

ii) 'The daily or short term variations of different conditions of lower air in terms of temperature, pressure, wind, rainfall, etc'.

iii) State of atmosphere at a particular time as defined by the various meteorological elements. (WMO)

The aspects involved in weather include small areas and duration, expressed in numerical values, etc. The different weather elements are solar radiation, temperature, pressure, wind, humidity, rainfall evaporation, etc. is highly variable. It changes constantly sometimes from hour to hour and at other times from day to day.

Climate

i) 'The generalized weather or summation of weather conditions over a given region during comparatively longer period'.

ii) 'The sum of all statistical information of weather in a particular area during a specified interval of time, usually, a season or a year or even a decade'.

iii) Synthesis of weather conditions in a given area, characterized by long-term statistics (mean values, variances, probabilities of extreme values, etc,) of the meteorological elements in that area. (WMO)

The aspects involved are larger areas like a zone, a state, a country and is described by normal. The climatic normals are generally worked out for a period of 30 years.

Differences between weather and climate:

Weather	Climate
1. A typical physical condition of the atmosphere.	1. Generalized condition of the atmosphere which represents and describes the

	characteristics of a region.
2. Changes from place to place even in a small locality	2. Different in different large region
3. Changes according to time (every moment)	3. Change requires longer (years) time.
4. Similar numerical values of weather of different places usually have same weather	4. Similar numerical values of climate of different places usually have different climates.
5. Crop growth, development and yield are decided by weather in a given season.	5. Selection of crops suitable for a place is decided based on climate of the region.
6. Under abnormal weather conditions planners can adopt a short-term contingent planning.	6. Helps in long-term agricultural planning.

Factors affecting climate

i) Latitude

The distance from the equator, either south or north, largely creates variations in the climate. Based on the latitude, the climate has been classified as

i) Tropical ii) Sub-tropical iii) Temperate & iv) Polar.

ii) Altitude (elevation)

The height from the MSL creates variation in climate. Even in the tropical regions, the high mountains have temperate climate. The temperature decreases by 6.5 ºC/Km from the sea level. Generally, there is also a decrease in pressure and increase in precipitation and wind velocity. The above factors alter the kind of vegetation, soil types and the crop production.

iii) Precipitation

The quantity and distribution of rainfall decides the nature of vegetation and the nature of the cultivated crops. The crop regions are classified on the basis of average rainfall which is as follow.

Rainfall(mm)	Name of the climatic region
Less than 500	Arid
500-750	Semi-arid
750-1000	Sub-arid
More than 1000	Humid

iv) Soil type

Soil is a product of climatic action on rocks as modified by landscape and vegetation over a long period of time. The colour of the soil surface affects the absorption, storage and re-radiation of heat. White colour reflects while black absorbs more radiation. Due to differential absorption of heat energy, variations in temperature are created at different places. In black soil areas, the climate is hot while in red soil areas, it is comparatively cooler due to lesser heat absorption.

v) Nearness to large water bodies

The presence of large water bodies like lakes and sea including its current affect the climate of the surrounding areas, eg: Islands and coastal areas. The movement of air from earth's surface and from water bodies to earth modifies the climate. The extreme variation in temperature during summer and winter is minimized in coastal areas and island.

vi) Topography

The surface of landscape (leveled or uneven surface areas) produces marked change in the climate. This involves the altitude of the place, steepness of the slope and exposure of the slope to light and wind.

vii) Vegetation

Kinds of vegetation characterize the nature of climate. Thick vegetation is found in tropical regions where temperature and precipitation are high. General types of vegetations present in a region indicate the nature of the climate of that region.

Scales of climate and their importance

i) Microclimate

Microclimate deals with the climatic features peculiar to small areas and with the physical processes that take place in the layer of air very near to the ground. Soil-ground conditions, character of vegetation cover, aspect of slopes, and state of the soil surface, relief forms – all these may create special local conditions of temperature, humidity, wind and radiation in the layer of air near the ground which differ sharply from general climatic conditions. One of the most important tasks of agricultural meteorology is to study the properties of air near the ground and surface layer of soil, which falls under the micro climate.

ii) Meso climate

The scale of meso climate falls between micro and macro climates. It is concerned with the study of climate over relatively smaller areas between 10 & 100 km across.

iii) Macro climate

Macro climate deals with the study of atmosphere over large areas of the earth and with the large scale atmospheric motions that cause weather. The scales of air motion in different climates are given in the Table below.

Type of climate	**Horizontal scale (km)**	**Vertical scale(km)**	**Time Scale(hrs)**
A. Macro climate			
1. Planetary scale	2000-5000 & more	10	200 to 400
2. Synoptic scale	500-2000	10	100
B. Meso climate	1 to 100	1-10	1-10

C. Micro climate	<100m	200 m	6-12 minutes

If any weather system develops under different types of climate, it persists longer periods under the macroclimate while smaller periods under micro climates.

CLIMATES OF INDIA AND TAMILNADU AND THEIR CHARACTERIZATION

Climate classification was tried by many scientists from beginning of 19th century using many parameters. Thornthwaite during 1931 and 1948 classified the climate using precipitation and evaporation /Potential evaporation and was subsequently modified by Mathur (1955) for the Moisture Index (Im) and is give below

Im = 100 [(P-PE)/PE]

Where P = Precipitation, PE = Potential evapo-transpiration

Using the moisture Index (**Im**) the following classification was made

Im Quantity	Climate classification
100 and above	Per humid
20 to 100	Humid
0 to 20	Moist sub humid
-33.3 to 0	Dry sub humid
-66.7 to -33.3	Semi arid
-100 to -66.7	Arid

Another classification by Troll (1965) based on number of humid months, said to be of more agricultural use was modified by ICRISAT for India. Humid month is one having mean rainfall exceeding the mean Potential evapo transpiration.

Climate	Number of humid months	% geographical area of India
Arid	<2.0	17.00
Semiarid-dry	2.0-4.5	57.17
Semiarid-wet	4.5-7.0	12.31
Humid	>7.0	1.10

The ICAR under All India Coordinated Research Project on Dryland Agriculture adopted classification based Moisture Deficit Index (MDI)

$$MDI = \frac{P - PET}{PET} \times 100$$

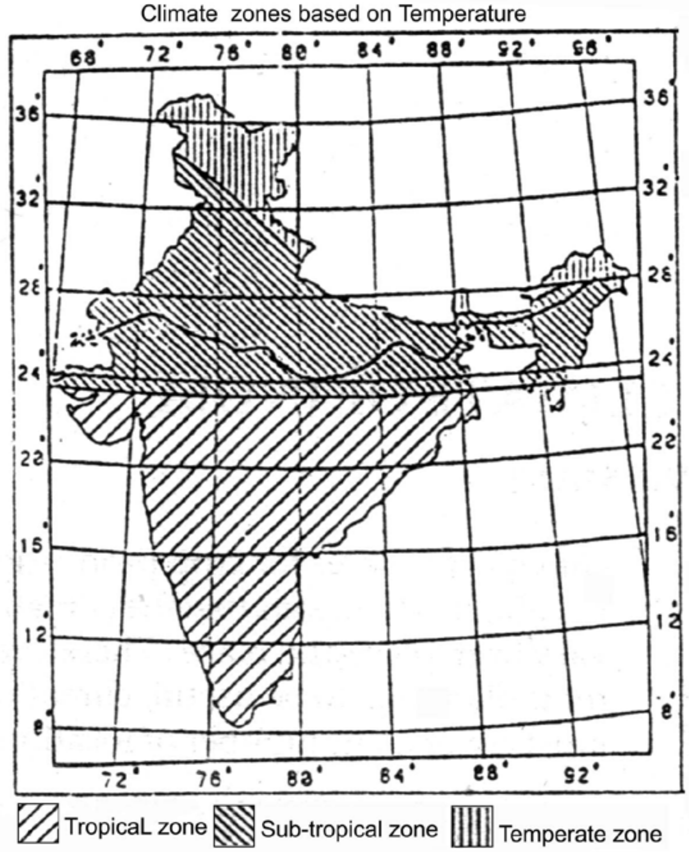
Where P is annual precipitation (cm) and PET is Potential Evapotranspiration. Based on MDI the climate is divided into three regions as below.

Type of climate	**MDI**
Subhumid	0.0 to 33.3
Semiarid	-33.3 to -66.6
Arid	> -66.6

Temperature based classification

The tropic of cancer, which passes through the middle of the country, divides it into two distinct climates. The tropical climate in the South where all the 12 months of the year have mean daily temperature exceeding 20°C; and in the North where a sub-tropical climate prevails. In sub-tropics during the winter months, it is cool to cold. Frosts occur sometime during the months of December and January. Some areas in the Northern India have a temperate climate. Here it snows during the winter months and freezing temperatures may extend to two months or more during the year. Three main climatic zones of India based on temperature are shown in the map below.

Climate zones based on Temperature



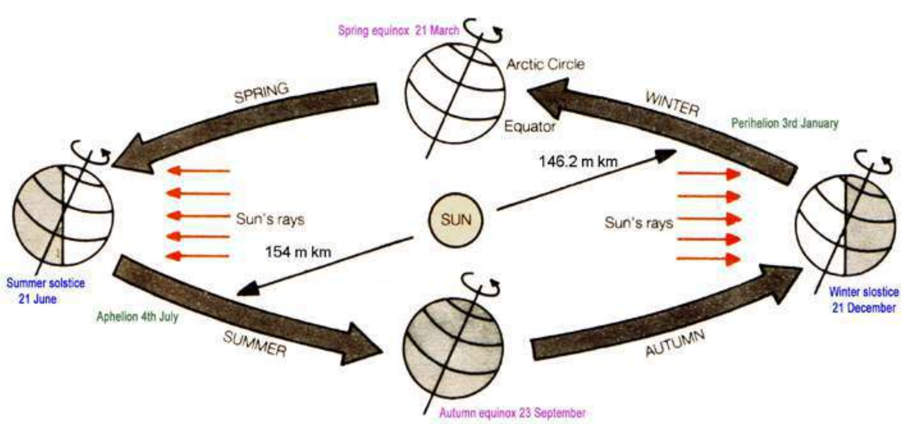
WEATHER ELEMENTS AND THEIR INFLUENCE ON DIFFERENT CROPS

The weather elements are solar radiation, temperature, soil temperature and light, radiation.

Solar radiation – Spectrum of radiation – Characteristics of different wave lengths and their effect on crop production.

Sun

- Sun is the prime source of energy
- Sun is the nearest star to the planet earth
- Diameter of the sun is 1.39 X 106 km
- It rotates on its axis about once every four weeks(27 days near equator & 30 days –polar)
- Sun is on an average 1.5 X 108 km away from the earth (149.64 M km deviation is 2.41 Mkm)
- Surface temperature of the sun is 5462° K
- Every minute, the sun radiates approximately 56 X 1026 calories of energy.
- The interior mass of the sun has a density of 80 to 100 times that of water.
- Energy is due to the fusion, Hydrogen is transformed to helium.
- 99% of the energy to biosphere is only from the sun and the rest one percent is from stars,lightning discharge, sun's radiation reflected from the moon, re-radiation from the earth etc.



Insolation

Electro magnetic energy radiated into the space by the sun

Factors affecting insolation

1. The solar constant which depends on

a. Energy output of the sun

b. Distance from earth to sun

2. Transparency of the atmosphere

3. Duration of daily sunlight period

4. Angle at which sun’s noon rays strike the earth.

Transfer of heat

All mater, at a temperature above the absolute zero, imparts energy to the surrounding space. Three processes viz. conduction, convection and radiation are involved in heat flow or heat transfer.

Conduction

Heat transfer through matter without the actual movement of the substances or matter. Heat flows from the warmer to cooler part of the body so that the temperatures between them are equalized. Eg. The energy transmission through an iron rod which is made warmer at one end.

Convection

Processes of transmission of heat through actual movement of molecules of the medium. This is predominant form of energy transmission on the earth as all the weather related processes involve this process. Eg. Boiling of water in a beaker

Radiation.

Transfer of energy from one body to another without the aid of the material medium (solid, liquid or gas). Radiation is not heat, only when radiation is absorbed by surface of a body heat is produced. Eg. The energy transmission through space from the sun to the earth.

Solar radiation

The flux of radiant energy from the sun is solar radiation.

Heavenly bodies emit – short wave radiation

Near surfaces including earth emit - long wave radiation

Radiation flux

The amount of radiant energy emitted, received, transmitted across a particular area is known as radiant flux.

Radiant flux density

The radiant flux divided by the area across which the radiation is transmitted is called radiant flux density.

Emissive power

The radiant flux density emitted by a source is called its emissive power.

Energy measurement

Units Cal	**cm-2 min-1**	**J cm-2 mi-1**	**W cm-2**
Cal cm-2 min-1	1	4.1868	0.069
J cm-2 mi-1	0.238	1	0.00165
W cm-2	14.3	60.6	1

Spectrum of Radiation

Band	Spectrum	Wavelength (μ)	Importance
Ultra	Cosmic rays	< 0.005	Shorter wave lengths of spectrum & Chemically active, unless filtered there is danger of life on earth
	Gamma rays and X-rays	0.005 – 0.20	
	Ultraviolet rays	0.20 – 0.39	
Visible	Violet	0.39 – 0.42	Visible spectrum known as Light essential for all plant processes
	Blue	0.42 – 0.49	
	Green	0.49 – 0.54	
	Yellow	0.54 – 0.59	
	Orange	0.59 – 0.65	
	Red	0.65 – 0.76	
Infra red	Infrared rays	> 0.76	Essential for thermal energy of the plant (Source of heat)

Units of measurements of wavelength

Micron 1μ = 10-6 m = 10-4 cm

Milli micron 1 mμ = 10-9 m = 10-7 cm

Angstrom Å = 10-10 m = 10-8 cm

Solar radiation and crop plants

Crop production is exploitation of solar radiation

Three broad spectra

1. Shorter than visible range: Chemically very active

- When plants are exposed to this radiation the effects are detrimental.
- Atmosphere acts as regulator for this radiation and none of cosmic, Gamma and Xrays

  reaches to the earth.
- The UV rays of this segment reaching to the earth are very low and it is normally tolerated by the plants.

2. Higher than visible wavelength

- Referred to IR radiation
- It has thermal effect on plants

- In the presence of water vapour, this radiation does not harm plants, rather it supplies the necessary thermal energy to the plant environment.

3. Visible spectrum

- Between UV & IR radiation and also referred as light
- All plant parts are directly or indirectly influenced by the light
- Intensity, quality and duration are important for normal plant growth
- Poor light leads to plant abnormalities
- Light is indispensable to photosynthesis
- Light affect the production of tillers, the stability, strength and length of Culms

It affects the yield, total weight of plant structures, size of the leaves and root development.

Critical stages of plant growth for light

- Radiation intensity during the third month of Maize plant

- Rice – 25 days prior to flowering

- Barley – flowering period

Band	Wavelength(nm)	Specific effect on plant
1.	Radiation within 1000 and more	No specific effect on plant activity. Radiation absorbed by plants are transformed into heat. This radiation does not interfere with bio-chemical processes.
2.	1000-720	Radiation in this band helps in plant elongation, can be accepted as an adequate measure of plant elongation activity. The far red region (700-920 nm) has important role on photo-periodism, germination of seeds, flowering and colouration of fruits.
3.	720-510	In this spectral region light is strongly absorbed by chlorophylls. It generates strong photosynthetic and photo-periodic activity.
4.	610-510	This is green-yellow region. Absorption in this spectral region has low photosynthetic effectiveness and weak formative activity.
5.	510-400	It is the strongest chlorophyll and yellow pigment absorption region. In the blue-violet range, photosynthetic activity becomes very strong. This region has very strong effect on formation of tissues.
6.	400-315	Radiation in this band produces formative effects. It has dwarfing effect on plants and thickening effect on plant leaf.
7.	315-280	Radiation in this band has detrimental effect on most plants
8.	Less than 280	Lethal effect most of the plants get killed due to radiation in this band UV ranges have germicidal action.

Radiation balance – Solar constant – albedo – Sensible heat – Heat energy – Latent heat

A part of the incident radiation on the surface is absorbed, while a part is reflected and the remaining is transmitted.

Absorptivity

Absorptivity of a substance is defined as the ratio of the amount of radiant energy absorbed to the total amount incident upon that substance. The absorptivity of a blackbody is unity. Natural bodies like sun and earth are near perfect black bodies

Reflectivity

Reflectivity is defined as the ratio of the radiant energy reflected to the total incident radiation upon that surface. If it is expressed in percentage it becomes albedo.

Transmittivity

Transmittivity is defined as ratio of the transmitted radiation to the total incident radiation

upon the surface.

Emissivity

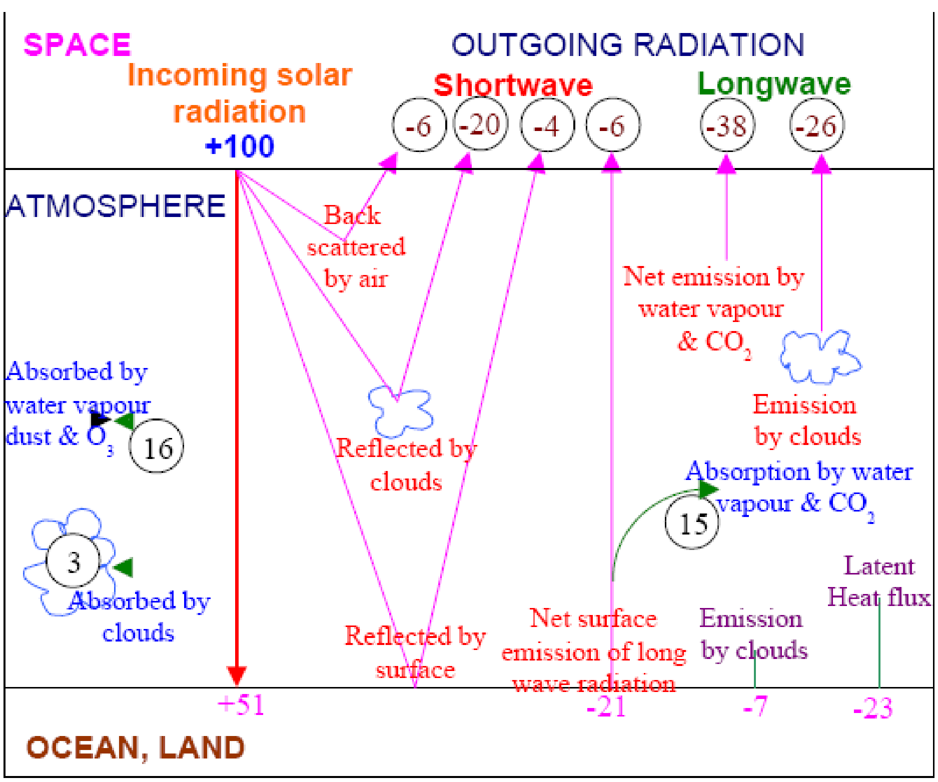
Emissivity is defined as the ratio of the radiant energy emitted by a given surface to the total heat energy emitted by a black body. The emissivity of a black body is unity.

Blackbody radiation

A Blackbody is defined as a body, which completely absorbs all the heat radiations falling on it without reflecting and transmitting any of it. It means reflectivity and transmittivity become zero. When such a black body is heated it emits radiation of all wavelengths depending upon its temp.

Radiation balance

The difference between all incoming and outgoing radiation at the earth's surface and top of the atmosphere is known as radiation balance at the earth's surface.



Solar constant

Solar constant is the energy received on a unit area at the outer most boundary of the earth (atmosphere) surface held perpendicular to the sun's direction, at the mean distance between the sun and the earth.

Solar constant is not a true constant. It fluctuates by as much as ± 3.5 % about its mean

value depending upon the distance of the earth from the sun.

Value is 2 cal / cm2 / min. (1.92 and 2.02) Recent measurements indicate value of 1.94

cal / cm2 / min (133 wm-2) [1 Langley = 1cal]

35% of the energy is contributed by U.V. and visible parts and 65% by Infra Red.

Albedo

It is the percentage of reflected radiation to the incident radiation. (Varies with colour and composition of the earth's surface, season, angle of the sun rays). Value is Highest in winter and at sunrise and sunset. Pure water – 5-20%, Vegetation 10-40%, Soils 15-50%, Earth 34-43% and clouds 55%. High albedo indicates that much of the incident solar radiation is reflected rather than absorbed.

Depends up on

1. Angle of incidence of radiation. Albedo increase with decreasing elevation of sun with minimum during noon.

2. Physical characteristics of surface

3. Season

4. Time of the day

For plant community albedo depends upon

1. Age of the crop

2. Percentage of ground cover

3. Colour and reflectivity of the foliage

Outgoing long wave radiation

After being heated by solar radiation, the earth becomes source of radiation.

Average temperature of the earth's surface 285º k (12º C)

99% of radiation is emitted in the farm of IR range (4 to 120 μ)

About 90% of the outgoing radiation is absorbed by the atmosphere.

Water vapour absorb in wavelengths of 5.3 to 7.7 μ and beyond 20μ.

Ozone 9.4 to 9.8 μ.

CO2 – 13.1 to 16.9 μ

Clouds – in all wavelengths

Long wave radiation escapes to the space between 8.5 and 11 μ and this is known as the **atmospheric window.** Atmosphere for this spectrum acts as transparent medium instead of absorbing. This spectral region is used in microwave remote sensing to monitor the features of the sky in case of overcast sky.

A large part of the radiation absorbed by the atmosphere is sent back to the earth's surface as counter – radiation. This counter radiation prevents the earth's surface from excessive cooling at night.

Radiation laws

The direct transfer of heat from the sun to the earth through the space and atmosphere indicates that radiation of heat from one place to other occurs in the form of electromagnetic waves in the same manner and with same speed of as light. The wavelength of electromagnetic radiation is given by the equation

$$\lambda = \frac{C}{V}$$

Where λ = Wavelength (The shortest distance between consecutive crests in the wave trance)

C = Velocity of light (3x1010 cm sec-1)

V = Frequency means number of vibrations of cycles per second

Plank's law

Plank introduced the 'particle concept'. The electromagnetic radiation consists of a stream or flow of particles or quanta, each quantum having energy content E determined by of each quantum is proportional to the frequency given by the equation.

E= h v where

h= Plank's constant (6.62x10-34 J sec-1

V= Frequency

The law states that greater the frequency (shorter wave length) greater is the energy of quantum.

Kirchoff's law

A good absorber of radiation is a good emitter, in similar circumstances. This law states that the absorptivity 'a' of an object for radiation of a specific wavelength is equal to the emissivity 'e' for the same wavelength. The equation of the law is :

$$a(\lambda) = e(\lambda)$$

Stefan-Boltzmann's law

The intensity of radiation emitted (E) by a radiating body is directly proportional to the fourth power of the absolute temperature of that body. (Emissivity of black body = 1)

E = σ T4

Where,

T= (273+°C) because temperature is in Kelvins

= Stefan-Boltzmann's constant which is equal to 5.673 x 10-8 W m-2 K-4

Wein's Displacement laws

The wavelength of the maximum intensity of emission (λmax) from a radiating black body is inversely proportional to its absolute temperature

$$\lambda_{max} = 2897\ T^{-1}\ \mu = 2897/T\ \mu \text{ Where T is in °K}$$

If the temperature of a body is high, radiation maximum is displaced towards shorter wavelengths. For the sun's surface temperature of 5793°K, the λ_{max} is 0.5μ (2897/5793). The most intense solar radiation occurs in the blue-green range of visible light. The wavelength of maximum intensity of radiation for the earth's actual surface temperature of 14°C or 287°K is about 10.0 (2897/287) microns, which is in the infrared band.

Energy balance or heat balance

The net radiation is the difference between total incoming and outgoing radiations and is a measure of the energy available at the ground surface. It is the energy available at the earth's surface to drive the processes of evaporation, air and soil heat fluxes as well as other smaller energy consuming processes such as photosynthesis and respiration. The net radiation over crop is as follows.

$$Rn = G + H + LE + PS + M$$

Rn is net radiation, G is surface soil heat flux, H is sensible heat flux, LE is laten heat flux, PS and M are energy fixed in plants by photosynthesis and energy involved in respiration, respectively. The PS and M are assumed negligible due to their minor contribution (about 1-2% of Rn). The net radiation is the basic source of energy for evapotranspiration (LE), heating the air (H) and soil (S) and other miscellaneous M including photosynthesis.

Temperature

It is defined as the measure of the average speed of atoms and molecules

Kinetic energy

Energy of motion.

Heat

It is the aggregate internal energy of motion and molecules of a body. It is often defined as energy in the process of being transferred from one object to another because of the temperature between them.

Sensible heat

It is the heat that can be measured by a thermometer and thus sensed by humans. Normally measured in Celsius, Fahrenheit and Kelvin.

Latent heat

It is the energy required to change a substance to a higher state of matter. This same energy is released on the reverse process. Change of state through Evaporation and condensation is known as latent heat of evaporation and latent heat of condensation. From water to water vapour takes 600 calories and water to ice takes 80 calories.

Blue colour of the sky

If the circumference of the scattering particle is less than about 1/10 of the wavelength of the incident radiation, the scattering co-efficient is inversely proportional to the fourth power of the wavelength of the incident radiation. This is known as **Rayleigh scattering**. This is the primary cause of the blue colour of the sky. For larger particles with circumference >30 times of wavelength of the incident radiation, scattering is independent of the wavelength (i.e) white light is scattered. This is known as **Mei scaring**

Red Colour of the sky at sunset & sunrise.

It is because of increased path length in the atmosphere. % of solar energy in the visible part decreases. With in the visible part, the ratio of the blue to the red part decreases with increased path length.

Disposition of Solar radiation

a. 25% of solar radiation is reflected back to the space by clouds (more by middle and high latitudes and less in the sub tropics)

b. 6% reflected back by air, dust and water vapour.

c. 30% scatted downwards (more in the form of shorter wavelengths able) them that in longer wave length (red).

d. 17% of solar radiation is absorbed by the atmosphere. (Mostly by Oxygen, O3, CO2 & H2O

vapour).

O_2 – absorb the extreme UV wavelengths (0.12 to 0.6 μ)

O_3 – UV (0.2 to 0.32 μ) and Visible part of radiation (0.44 to 0.7 μ)

H_2O vapour – Near infra red (0.93, 1.13, 1.42 μ)

CO_2 - IR band 2.7 μ.

e. About 50% of solar radiation reaches earth's surface, after reflection, scattering and absorption.

LIGHT – EFFECT OF LIGHT INTENSITY, QUALITY, DIRECTION AND DURATION ON CROP PRODUCTION – AIR TEMPERATURE – FACTORS AFFECTING TEMPERATURE.

Light

Light is the visible portion of the solar spectrum with wavelength range is from 0.39 to 0.76μ. Light is one of the important climatic factors for many vital functions of the plant. It is essential for the synthesis of the most important pigment ie. Chlorophyll, Chlorophyll absorbs the radiant energy and converts it into potential energy of carbohydrate. The carbohydrate thus formed is the connecting link between solar energy and living world. In addition, it regulates the important physiological functions. The characteristics of light viz. intensity, quality, duration and direction are important for crops.

Light intensity

- The intensity of light is measured by comparing with a standard candle. The amount of light received at a distance of one metre from a standard candle is known as "Metre candle or Lux". The light intensity at one foot from a standard candle is called 'foot candle' or 10.764 luxes and the instrument used is called as lux metre.
- About one percent of the light energy is converted into biochemical energy.
- Very low light intensity reduces the rate of photosynthesis resulting in reduced growth.
- Similarly, very high intensity is detrimental to plant in many ways as below.
- It increases the rate of respiration.
- It also causes rapid loss of water (ie) increases the transpiration rate of water from the plants.
- The most harmful effect of high intensity light is that it oxidises the cell contents which is termed as 'Solarisation'. This oxidation is different from respiration and is called as photo-oxidation.
- Under field conditions the light is not spread evenly over the crop canopy but commonly passed by reflection and transmission through several layers of leaves.
- The intensity of light falls at exponential rate with path length through absorbing layers according to Beer's law. ie the relative radiation intensity decreases exponentially with increasing leaf area.
- At ground level the light intensity is below the light compensation point (The light intensity at which the gas exchange resulting from photosynthesis is equal to that resulting from respiration)

Based on the response to light intensities the plants are classified as follows.

(i) Sciophytes (shade loving plants): The plants grow better under partially shaded conditions. (eg) Betel vine, buck wheat etc.

(ii) Hetrophytes (Sun loving): Many species of plants produce maximum dry matter under high light intensities when the moisture is available at the optimum level. (eg) Maize, sorghum, rice etc.

Quality of Light

When a beam of white light is passed through a prism, it is dispersed into wavelengths of different colours. This is called the visible part of the solar spectrum. The different colours and their wave length are as follows:

Violet 400 – 435 m μ	Blue 435 – 490 m μ
Green 490 – 574 m μ	Yellow 574 – 595 m μ
Orange 595 – 626 m μ	Red 626 – 750 m μ

The principal wavelength absorbed and used in photosynthesis are in the violet – blue and the orange - red regions. Among this, short rays beyond violet such as X rays, gamma rays and larger rays beyond red such as infrared, are detrimental to plant growth. Red light is the most favourable light for growth followed by violet – blue. Ultra – violet and shorter wave lengths kill bacteria and many fungi.

c) Duration of light

The duration of light has greater influence than the intensity for canopy development and final yield. It has a considerable importance in the selection of crop varieties. The response of plants to the relative length of the day and night is known as phtoperiodism. The plants are classified based on the extent of response to day length which is as follows.

(i) Long day plants

The plants which develop and produce normally when the photoperiod is greater than the critical minimum (greater than 12 hours). eg. Potato, Sugarbeet, Wheat, Barley etc.

(ii) Short day plants

The plants which develop normally when the photoperiod is less than the critical maximum (less than 12 hours). Rice, Sorghum, cotton, Sunflower

(iii) Day neutral plants / Indeterminate

Those plants which are not affected by photoperiod.

(eg) Tomato, Maize

The photoperiodism influences the plant character such as floral initiation or development, bulb and rhizome production etc. In long day plant, during periods of short days, the growth of internodes are shortened and flowering is delayed till the long days come in the season. Similarly when short day plants are subjected to long day periods, there will be abnormal vegetative growth and there may not be any floral initiation.

Direction of light

- The direction of sunlight has a greater effect on the orientation of roots and leaves.
- In temperate regions, the southern slopes plants produce better growth than the northern slopes due to higher contribution of sunlight in the southern side.
- The change of position or orientation of organs of plants caused by light is usually called as phototropism ie the leaves are oriented at right angles to incidence of light to receive maximum light radiation.

Photomorphogenesis

Change in the morphology of plants due to light. This is mainly due to U.V and violet ray of the sun.

AIR TEMPERATURE

Temperature is defined as, “The measure of speed per molecule of all the molecules of a body”. Where as heat is, “the energy arising from random motion of all the molecules of a body'. (Degree of molecular activity). It is the intensity aspect of heat energy.

Conduction

Heat transfer when two bodies of unequal temperatures come into contact. Heat passes from point to point by means of adjacent molecules.

Convection

Transfer through movement of particles (part of mass) in fluids and gasses. These ar able to circulate internally and distribute heated part of the mass.

Radiation

It is the process of transmission of energy by electromagnetic waves between two bodies without the necessary aid of an intervening material medium.

Factors affecting air temperature

i. Latitude

ii. Altitude

iii. Distribution of land and water

iv. Ocean currents

v. Prevailing winds

vi. Cloudiness

vii. Mountain barriers

viii. Nature of surface

ix. Relief

x. Convection and turbulence etc.

1. Latitude

The time of occurrence of maximum monthly mean temperature and minimum monthly mean temperature also depends on latitude of a place. (eg.) The coldest month is January in northern regions of India while December in the south. Similarly, the warmest month is May in the south while June in the north across the country.

2. Altitude

The surface air temperature decreases with increasing altitude from the mean sea level as the density of air decreases. Since the density of air is less at higher altitudes, the absorbing capacity of air is relatively less with reference to earth's longwave radiation.

3. Distribution of land and water

Land and water surfaces react differently to the insolation. Because of the great contrasts between land and water surfaces their capacity for heating the atmosphere varies. Variations in air temperature are much greater over the land than over the water. The differential heating process between land and sea surfaces are due to their properties. It is one of the reasons for Indian monsoon.

4. Ocean currents

The energy received over the ocean surface carried away by the ocean currents from the warm areas to cool areas. This results in temperature contrast between the equator and poles. The occurrence of El-Nino is due to change in sea surface temperature between two oceanic regions over the globe.

5. Prevailing winds

Winds can moderate the surface temperature of the continents and oceans. In the absence of winds, we feel warm in hot climates. At the same time, the weather is pleasant if wind blows.

6. Cloudiness

The amount of cloudiness affects the temperature of the earth's surface and the atmosphere. A thick cloud reduces the amount of insolation received at a particular place and thus the day time temperature is low. At the same time, the lower layers in the atmosphere absorb earth’s radiation. This results in increasing atmospheric temperature during night. That is why, cloudy nights are warmer. This is common in the humid tropical climates.

7. Mountain barriers

Air at the top of the mountain makes little contact with the ground and is therefore cold while in the valley at the foothills makes a great deal of contact and is therefore warm. That is, the lower region of the earth’s atmosphere is relatively warmer when compared to hillocks.

Diurnal and seasonal variation of air temperature

- The minimum air temperature occurs at about sunrise, after which there is a constant

  rise till it reaches to maximum.
- The maximum air temperature is recorded between 1300 hrs and 1400 hrs although the

  maximum solar radiation is reaches at the moon.
- A steady fall in temperature till sunrise is noticed after is attains maximum. Thus the daily March displays one maximum and one minimum. The difference between the two is called the diurnal range of air temperature.
- The diurnal range of air temperature is more on clear days while cloudy weather sharply reduces daily amplitudes.
- The diurnal range of temperature is also influenced by soils and their coverage in addition to seasons.
- Addition of daily maximum and minimum temperature divided by two is nothing but daily mean / average temperature.
- In northern hemisphere winter minimum occurs in January and summer maximum in July.

Horizontal air temperature distribution

- The lines connecting points of equal temperature is called as **isotherm**
- It is largely depends latitude. A general decrease in temperature from equator towards poles is one of the most fundamental factors of climatology.
- Irregular distribution of land and water on earth's surface breaks the latitudinal variation in temperature.
- Land areas warm and cool rapidly than water bodies
- Mountain barriers influence horizontal distribution of temperature by restricting movement of air masses.
- On local scale topographic relief exerts an influence on temperature distribution.

Vertical air temperature distribution

Decrease in temperature with increase in height

Temperature inversion

- Occasionally at some altitude the temperature abruptly increases instead of decreasing. This condition in which this abrupt rise instead of fall in temperature occurs in the air is known as the temperature inversion. This may occurs under the following conditions.
- When the air near the ground cools off faster than the overlying layer, because of heat loss during cooling nights.
- When an actual warm layer passing over a lower cold layer
- Cold air from hill tops and slopes tend to flow downward and replaced by warm air.

Significance of Temperature inversion

- Cloud formation, precipitation and atmospheric visibility are greatly influenced by inversion phenomenon

- Fog formation may take place near the ground which may affect the visibility to both human beings and animals. Affects air navigation.
- Diurnal temperature is affected by temperature inversions.
- The incoming solar radiation and its conversion in to heat is affected.

Heat Units

- It is a measure of relative warmth of growing season of a given length. Normally it is indicated as Growing Degree Days (GDD). A heat unit is the departure from the mean daily temperature above the minimum threshold temperature.
- The minimum threshold temperature is the temperature below which no growth takes place.
- Usually ranges from 4.5 to 12.5 ºC for different crops (Most commonly used value is 6.0ºC)

Degree Day

A degree day is obtained by subtracting the threshold temperature from daily mean temperature. Summation of the daily values over the growth period gives degree days of the crops.

$$GDD = \Sigma \frac{T_{max} + T_{min}}{2} - T_b$$

Where

T_{max} – Maximum air temperature of the day

T_{min} – Minimum air temperature of the day

T_b - Base temperature of the crop

The base temperature is the threshold temperature.

Advantages / Importance of growing degree Day Concept

1. In guiding the agricultural operations and planting land use.
2. To forecast crop harvest dates, yield and quality

3. In forecasting labour required for agricultural operations

4. Introduction of new crops and new varieties in new areas

5. In predicting the likelihood of successful growth of a crop in an area.

HEAR INJURIES

'Thermal death point" – the temperature at which the plant cell gets killed when the temperature ranges from 50-60°C. This varies with plant species. The aquatic and shade loving plants are killed at comparatively lower temperature (40°C).

High temperature

- results in desiccation of plants
- disturbs the physiological activities like photosynthesis and respiration
- increases respiration leading to rapid depletion of reserve food.

Sun clad

Injury caused on the barks of stem by high temperature during day time and low temperature during the night time.

Stem griddle

The stem at ground level scorches around due to high soil temperature. It causes death of plant by destroying conductive tissues. Eg. This type of injury is very common in young seedlings of cotton in sandy soil when soil temperature exceeds 60°C.

COLD INJURY

(i) Chilling injury

Plants which are adapted to hot climate, if exposed to low temperature for sometime, are found to be killed or severely injured or development of chloratic condition (yellowing) (eg.) cholratic bands on the leaves of sugarcane, sorghum and maize in winter months when the night temperature is below 20°C.

(ii) Freezing injury

This type of injury is commonly observed in plants of temperate regions. When the plants are exposed to very low temperature, water freezes into ice crystals in the intercellular spaces of plants. The protoplasm of cell is dehydrated resulting in the death of cells. (eg.) Frost damage in potato, tea etc.

(iii) Suffocation

In temperature regions, usually during the winter season, the ice or snow forms a thick cover on the soil surface. As a result, the entry of oxygen is prevented and crop suffers for want of oxygen. Ice coming in contact with the root prevents the diffusion of CO2 outside the root zone. This prevents the respiratory activities of roots leading to accumulation of harmful substances.

(iv) Heaving

This is a kind of injury caused by lifting up of the plants along with soil from its normal position. This type of injury is commonly seen in temperate regions. The presence of ice crystals increases the volume of soil. This causes mechanical lifting of the soil.

Role of temperature in crop production:

1. Temperature influences distribution of crop plants and vegetation.
2. The surface air temperature is one of the important variables, which influences all stages of crop during its growth development and reproductive phase.
3. Air temperature affects leaf production, expansion and flowering.
4. The diffusion rates of gases and liquid changes with temperature.
5. Solubility of different substances is dependent on temperature.
6. Biochemical reactions in crops (double or more with each 10°C rise) are influenced by air temperature.
7. Equilibrium of various systems and compounds is a function of temperature.
8. Temperature affects the stability of enzymatic systems in the plants.

9. Most of the higher plants grow between 0°C – 60°C and crop plants are further restricted from 10 – 40°C, however, maximum dry matter is produced between 20 and 30°C

10. At high temperature and high humidity, most of the crop plants are affected by pests and diseases.

11. High night temperature increases respiration and metabolism.

12. A short duration crop becomes medium duration or long duration crop depending upon its environmental temperature under which it is grown.

13. Most of the crops have upper and lower limits of temperature below or above which, they may not come up and an optimum temperature when the crop growth is maximum. These are known as cardinal temperatures and different crops have different temperatures.

Sl No	Crop	Minimum	Optimum	Maximum
1	Wheat and Barley	0 – 5	25 – 31	31 – 37
2	Sorghum	15 – 18	31 – 36	40 – 42

Thermo periodic response

Response of living organism to regular changes in temperature either day or night or seasonal is called thermoperiodism.

Soil temperature

The soil temperature is one of the most important factors that influence the crop growth. The sown seeds, plant roots and micro organisms live in the soil. The physio-chemical as well as life processes are directly affected by the temperature of the soil. Under the low soil temperature conditions signification is inhibited and the intake of water by roof is reduced. In a similar way extreme soil temperatures injures plant and its growth is effected.

Eg. On the sunny side, plants are likely to develop faster near a wall that stores and radiates heat. If shaded by the wall, however, the same variety may mature later. In such cases soil temperature is an important factor.

Importance of soil temperature on crop plants:

The soil temperature influences many process.

1. Governs uptake of water, nutrients etc needed for photosynthesis.
2. Controls soil microbial activities and the optimum range is 18-30°C.
3. Influences the germination of seeds and development of roots.
4. Plays a vital role in mineralization of organic forms of nitrogen.(inc with inc in temp)
5. Influences the presence of organic matter in the soil.(more under low soil temperature)
6. Affects the speed of reactions and consequently weathering of minerals.
7. Influences the soil structure (types of clay formed, the exchangeable ions present, etc.)

Factors affecting soil temperature:

Heat at ground surface is propagated downward in the form of waves. The amplitude deceases with depth. Both meteorological and soil factors contribute in bringing about changes of soil temperature.

I) Meteorological factors

1. Solar radiation

a) The amount of solar radiation available at any given location and point of time is directly proportional to soil temperature.

b) Even though a part of total net radiation available is utilised in evapotranspiration and heating the air by radiation (latent and sensible heat fluxes) a relatively substantial amount of solar radiation is utilized in heating up of soil (ground heat flux) depending up on the nature of surface.

c) Radiation from the sky contributes a large amount of heat to the soil in areas where the sun's rays have to penetrate the earth's atmosphere very obliquely.

2. Wind

Air convection or wind is necessary to heat up the soil by conduction from the atmosphere.

(eg.) The mountain and valley winds influence the soil temperature.

3. Evaporation and condensation

a) The greater the rate of evaporation the more the soil is cooled. This is the reason for coolness of moist soil in windy conditions.

b) On the other hand whenever water vapour from the atmosphere or from other soil depths condenses in the soil it heats up noticeably. Freezing of water generates heat.

4. Rainfall (Precipitation)

Depending on its temperature, precipitation can either cool or warm the soil.

II. Soil factors

1. Aspect and slope

a) In the middle and high latitudes of the northern hemisphere, the southern slopes receive more insolation per unit area than the northern exposure.

b) The south west slopes, are usually warmer than the south east slopes. The reason is that the direct beam of sunshine on the south east slope occur shortly after prolonged cooling at night, but the evaporation of dew in the morning also requires energy.

2. Soil texture

a) Because of lower heat capacity and poor thermal conductivity, sandy soils warm up more rapidly than clay soils. The energy received by it is concentrated mainly in a thin layer resulting in extraordinary rise in temperature.

b) Radiational cooling at night is greater in light soils than in heavy soils. In the top layer, sand has the greatest temperature range, followed by loam and clay.

c) The decrease of range with depth is more rapid in light soils than heavy soils when they are dry but slower when they are wet.

d) A soil with rough surface absorbs more solar radiation than one with a smooth surface.

3. Tillage and Tilth

a) By loosening the top soil and creating a mulch, tillage reduces the heat flow between the surface and the sub soil.

b) Since, the soil mulch has a greater exposure surface than the undisturbed soil and no capillary connection with moist layers below, the cultivated soil dries up quickly by evaporation, but the moisture in the sub-soil underneath the dry mulch is conserved.

c) In general soil warms up faster than air. The diurnal temperature wave of the cultivated soil has a much larger amplitude than that of the uncultivated soil.

d) The air 2-3 cm above the tilled soil is often hotter (10°C or above) than that over an untilled soil.

e) At night loosened ground is colder and more liable to frost than the uncultivated soil.

4. Organic matter:

a) The addition of organic matter to a soil reduces the heat capacity and thermal conductivity. But, the water holding capacity increases.

b) The absorbtivity of the soil increases because of the dark colour of the organic matter.

c) At night, the rapid flow of heat from sub-soil by radiation is reduced with the addition of organic matter because of its low thermal conductivity.

d) The darker the colour, the smaller the fraction of reflected radiation.

e) The dark soils and moist soils reflect less than the light coloured and dry soils.

5. Soil moisture

a) Moisture has an effect on heat capacity and heat conductivity.

b) Moisture at the soil surface cools the soil through evaporation.

c) Therefore, a moist soil will not heat up as much as a dry one.

d) Moist soil is more uniform in temperature throughout its depth as it is a better conductor of heat than the dry soil.

Variations in soil temperature:

There are two types of soil temperature variations; daily and seasonal variation of soil temperature

1. Daily variations of soil temperature:

a) These variations occur at the surface of the soil.

b) At 5 cm depth the change exceeds 10°C. At 20 cm the change is less and at 80 cm diurnal changes are practically nil.

c) On cooler days the changes are smaller due to increased heat capacity as the soils become wetter on these days.

d) On a clear sunny day a bare soil surface is hotter than the air temperature.

e) The time of the peak temperature of the soil reaches earlier than the air temperature due to the lag of the air temperature.

f) At around 20 cm in the soil the temperature in the ground reaches peak after the surface reaches its maximum due to more time the heat takes to penetrate the soil. The rate of penetration of heat wave within the soil takes around 3 hours to reach 10 cm depth.

g) The cooling period of the daily cycle of the soil surface temperature is almost double than the warming period.

h) Undesirable daily temperature variations can be minimised by scheduling irrigation.

2. Seasonal variations of soil temperature:

a) Seasonal variations occur much deeper into the soil.

b) When the plant canopy is fully developed the seasonal variations are smaller.

c) In winter, the depth to which the soil freezes depends on the duration and severeness of the winter.

d) In summer the soil temperature variations are much more than winter in tropics and sub tropics.

HUMIDITY –ABSOLUTE HUMIDITY – SPECIFIC HUMIDITY –RELATIVE HUMIDITY – MIXING RATIO, DEW POINT TEMPERATURE – VAPOUR PRESSURE DEFICIT – DIURNAL VARIATION IN RELATIVE HUMIDITY AND ITS EFFECT ON CROP PRODUCTION.

Humidity

The amount of water vapour that is present in atmosphere is known as atmospheric moisture or humidity.

Absolute humidity

The actual mass of water vapour present in a given volume of moist air. It is expressed as grams of water vapour per cubic meter or cubic feet.

Specific humidity

Weight of water vapour per unit weight of moist air. It is expressed as grams of water vapour per kilogram of air (g/kg).

Mixing ratio

The ratio of the mass of water vapour contained in a sample of moist air to the mass of dry air. It is expressed as gram of water vapour per kilogram dry air.

Relative Humidity

The ratio between the amount of water vapour present in a given volume of air and the amount of water vapour required for saturation under fixed temperature and pressure. There are no units and this is expressed as percentage. In other terms it is the ratio of the air's water vapour content to its maximum water vapour capacity at a given temperature expressed in percentage. The relative humidity gives only the degree of saturation of air. The relative humidity of saturated air is 100 per cent.

Dew Point temperature

The temperature to which a given parcel of air must be cooled in order to become saturation at constant pressure and water vapour content. In this case, the invisible water vapour begins to condense into visible form like water droplets.

Vapour Pressure deficit

The difference between the saturated vapour pressure (SVP) and actual vapour pressure (AVP) at a given temperature. This is an another measure of moisture in the atmosphere which is useful in crop growth studies. When air contains all the moisture that it can hold to its maximum limit, it is called as saturated air, otherwise it is unsaturated air, at that temperature. The vapour pressure created at this temperature under saturated conditions is vapour pressure or saturated vapour pressure (SVP).

Importance of Humidity on crop plants

The humidity is not an independent factor. It is closely related to rainfall, wind and temperature. It plays a significant role in crop production.

1. The humidity determines the crops grown in a given region.
2. It affects the internal water potential of plants.
3. It influences certain physiological phenomena in crop plants including transpiration
4. The humidity is a major determinant of potential evapotranspiration. So, it determines the water requirement of crops.
5. High humidity reduces irrigation water requirement of crops as the evapotranspiration losses from crops depends on atmospheric humidity.
6. High humidity can prolong the survival of crops under moisture stress. However, very high or very low relative humidity is not conducive to higher yields of crops.
7. There are harmful effects of high humidity. It enhances the growth of some saprophytic and parasitic fungi, bacteria and pests, the growth of which causes

extensive damage to crop plants. Eg: a. Blight disease on potato. b. The damage caused by thrips and jassids on several crops.

8. High humidity at grain filling reduces the crop yields.

9. A very high relative humidity is beneficial to maize, sorghum, sugarcane etc, while it is harmful to crops like sunflower and tobacco.

10. For almost all the crops, it is always safe to have a moderate relative humidity of above 40%.

Variation in Humidity:

1. Absolute humidity is highest at the equator and minimum at the poles.

2. Absolute humidity is minimum at sunrise and maximum in afternoon from 2 to 3 p.m. The diurnal variations are small in desert regions.

3. The relative humidity is maximum at about the sunrise and minimum between 2 to 3 p.m.

4. The behaviour of relative humidity differs a lot from absolute humidity. At the equator it is at a maximum of 80 per cent and around 85 per cent at the poles. But, near horse latitudes it is around 70 per cent.

MONSOON

Atmospheric pressure

The atmospheric pressure is the weight of the air, which lies vertically above a unit area centered at a point. The weight of the air presses down the earth with the pressure of 1.034 gm / cm2. It is expressed in millibar (mb) equal to 100 N/m2 or 1000 dynes/cm2. Unequal heating of the earth and its atmosphere by the sun and rotation of the earth bring about differences in atmospheric pressure.

Isobars

The distribution of pressure is represented on maps by 'isobars'. Isobars are defined as the imaginary lines drawn on a map to join places having the same atmospheric pressure.

Diurnal and seasonal variation

(a) Diurnal pressure variation

a. There is a definite rhythm in the rise and fall of the pressure in a day.

b. Radiational heating (air expansion) and radiational cooling (air contraction) are the main reasons for diurnal variation in the air pressure.

c. Diurnal variation is more prominent near the equator than at the mid latitudes.

d. The areas closer to sea level record relatively larger amount of variation than in land areas.

e. Equatorial regions absorbs more heat than it loses while the polar region gives up more heat than they receive

b) Seasonal pressure variation

a. Due to the effect caused by annual variation in the amount of insolation, distinct seasonal pressure variations occur.

b. These variations are larger in the tropical region than the mid latitude and polar regions.

c. Usually, high pressures are recorded over the continents during the cold season and over the oceans during the warm season.

Pressure systems of the world

The shape of the earth is not uniform and subjected to uneven distribution of solar radiation, when it revolves around the sun. The uneven distribution of solar radiation over different regions of the globe leads to contrast in surface air temperature. This results in variations of surface atmospheric pressure systems, which are known as standard atmospheric pressure systems / belts. There are altogether seven alternating low and high pressure belts on the earth's surface. They are as follows:

i. Equatorial trough of low pressure (between 5°N and 5°S)

ii. Subtropical high pressure belt (Northern hemisphere) (25° and 35°N)

iii. Subtropical high pressure belt (Southern hemisphere) (25° and 35°S)

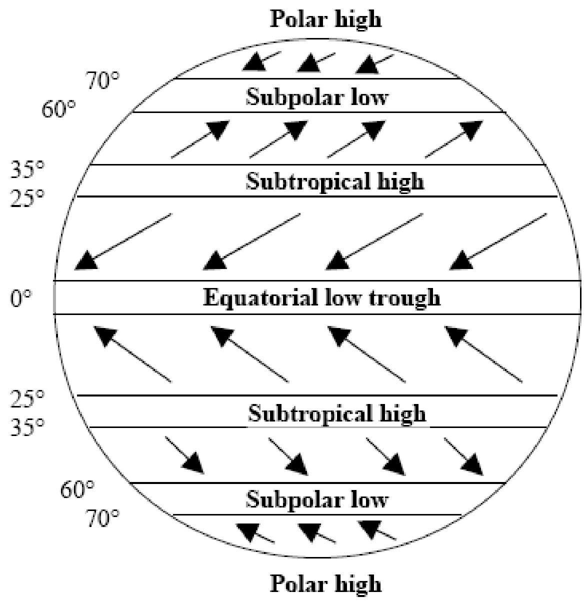
iv. Subpolar low pressure belt (Northern hemisphere) (60° and 70°N)

v. Subpolar low pressure belt (Southern hemisphere) (60° and 70°S)

vi. Polar high (Northern hemisphere)

vii. Polar high (Southern hemisphere)

The equatorial region receives more solar radiation and thus the surface air temperature is high, which creates lighter air near the ground compared to higher latitudes. The above condition leads to low atmospheric pressure over the equatorial region while sub tropical high pressure belts develop in both the hemispheres between 25 and 35 degree latitudes due to relatively low surface air temperature. It is due to low solar radiation received due to inclined sun's rays over the subtropical region when compared to the equatorial belt. Like wise alternate low and high atmospheric pressure belt systems are developed across the globe from the equator to the poles.



Causes of variation

The atmospheric pressure changes continuously due to several factors. The most important factors are changes with temperature, altitude, water vapour content and rotation of earth.

a) Temperature

Hot air expands and exerts low pressure. Cold air contracts and exerts high pressure. So the equator has a low pressure due to prevalence of high temperature but poles have a high pressure.

b) Altitude

At sea level, the air column exerts its full pressure, but when we stand on a hill or when we go in the upper layers of atmosphere, we leave a portion of air which cannot exert its full pressure. At sea level, a coastal town enjoys high pressure but on high altitude one will register a low pressure. For every 10 m of ascend, the pressure get reduced by 1 hPa.

c) Water vapour

The water vapour content is lighter in cold area than in air which is dry with the result that moist air of a high temperature exerts a less pressure when compared to cold air.

d) Rotation of the earth

On account of rotation of the earth, the pressure at 60-70°N and S becomes low. The rotation of the earth near sub-polar belts, makes the air to escape from these belts which move towards the horse latitude (30° - 35°N and 30 – 35°S). These latitudes absorb the air from sub polar belts making the pressure high. G.D.Coriolis (1844) a French Mathematician indicated that air is deflected towards right in the Northern Hemisphere and Left in the Southern hemisphere due to rotation of earth and this was termed after him as Coriolis force. Coriolis force is not actually a force but it is effect created by rotation of earth.

Low / Depression

When the isobars are circular or elliptical in shape, and the pressure is lowest at the centre, such a pressure system is called 'Low' or 'Depression' or 'Cyclone'. The movement will be anti-clockwise in the Northern hemisphere while it is clockwise in the southern hemisphere. Wind spped hardly exceeds 40 km per hour.

Anticyclone

When isobars are circular, elliptical in shape and the pressure is highest at the centresuch a pressure system is called 'High' or 'Anticyclone'. When the isobars are elliptical rather than circular the system is called as 'Ridge' or 'Wedge'. The movement will be clockwise in the Northern hemisphere while it is anti-clockwise in the southern hemisphere.

Storm

Low pressure centre surrounded by winds having their velocities in the range of 40 to 120 km/hour. A more favourable atmosphere condition for their occurrence exists during the summer season. The Bay of Bengal and Arabian sea offer ideal condition for origin and growth of the storms. These storms produce heavy precipitation and bring about a change in the existing weather. It occurs very rarely. It causes wide spread damage.

Hurricane

A severe tropical cyclone with wind speed exceeding 120 km per hour. The name hurricane is given to the tropical cyclones in the North Atlantic and the eastern North Pacific Ocean. The tropical cyclones of Hurricane force in the western North pacific are known as typhoons. In Australia this type of storm is given the name willy-willy, whereas in the Indian Ocean they are called as Cyclones. Hurricanes are fueled by water vapour (i.e.) pushed up from the warm ocean surface, so they can last longer and sometimes move much further over water than over land. A combination of heat and moisture along with the right wind conditions can create a new hurricane.

Thunderstorms

Storms produced by cumulonimbus clouds and always accompanied by lightening and thunder. They are usually of short duration, seldom over 2 hours. They are also accompanied by strong wind gusts, heavy rain and sometimes hail.

Tornadoes

Defined as a violently rotating column of air attended by a funnel-shaped or tubular cloud extending downward from the base of cumulonimbus cloud. Tornadoes are the most violent storms of lower troposphere. They are very small in size and of short duration. They mostly occur during spring and early summer. They have been reported at widely scattered locations in the mid latitudes and tropics. Crop losses are heavy due to this event. Unknown in other parts of the world.

Waterspouts

It is column of violently rotating air over water having a similarity to a dust devil of tornado. In other words, tornadoes are weak visible vortices occurring over water are called waterspouts. They are formed over tropical and subtropical oceans.

Wind

Air in horizontal motion is known as wind. Vertical movement is noticed but negligibly small compared to horizontal movement as the height of the atmosphere is only for few kilometers. However vertical movement or uplift of air only causes significant weather changes in cloud formation and rain.

Wind systems of the world

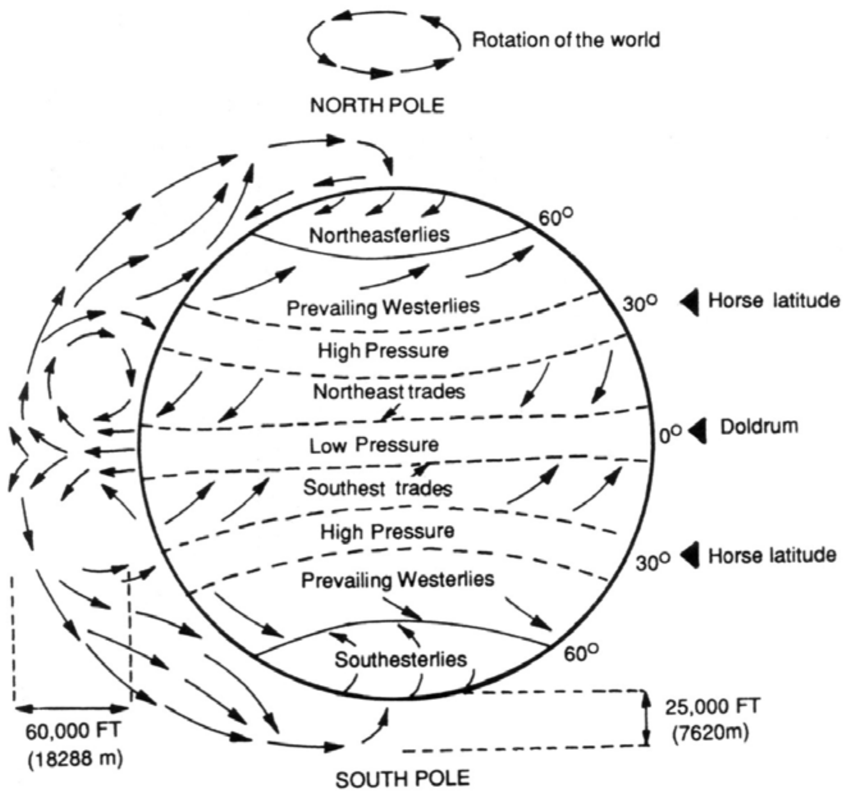
The wind belts found on earth's surface in each hemisphere are:

a. Doldrums

b. Trade wind belt

c. Prevailing westerlies

d. Polar easterlies



GLOBAL WIND CIRCULATION

1. Doldrums

Owing to continuous heating of the earth by insolation, pressures are low and winds converge and rise near the equator. This intertropical convergent zone is known as 'Doldrums'.

a) These are the equatorial belts of calms and variable winds.

b) The location is 5°S and 5°N latitudes.

c) Wind is light due to negligible pressure gradient.

d) Mostly, there are vertical movements in the atmosphere.

e) The atmosphere is hot and sticky.

2. Trade winds (Tropical Easterlies)

a) The regular high temperature at the equator results in a high pressure forming in the upper levels of the equator.

b) Then, the air is transferred to the northward and southward directions until 35° North and South in both the hemisphere.

c) Due to this reduction in surface pressure on the equator (doldrums) there is an increase in pressure at 35°N and 35°S which are known as horse latitude (sub-tropical high).

d) As a result, the winds flow from the horse latitude to the equatorial region.

e) While moving, these winds are deflected by Coriolis force to the right in northern hemisphere and to the left in southern hemisphere.

f) These winds flow from 35°N to the equator in NE direction in the northern hemisphere and from 35°S to the equator in SE direction in the southern hemisphere. These are known as 'Trade winds'. These are known as 'Tropical easterlies'.

g) These are most constant winds in force and direction and flow over nearly half the globe.

3. Anti-trade winds

a) This is a supplementary wind system of the earth which is effective at higher levels.

b) This system works in opposite direction to the surface winds.

c) The anti-trade winds mostly flow from land to ocean and brings no rain.

4. Prevailing Westerlies

a) The winds that flow from sub-tropical high to the low-pressure area about 60-70° latitudes in both the hemispheres are known as 'Prevailing westerlies'.

b) In the northern hemisphere the direction of Prevailing westerlies is SW and in southern hemisphere NW.

c) These winds are forceful and are irregular as compare to the trade winds in the tropical regions.

d) High precipitation zone

5. Polar Easterlies / Polar winds

b) A permanent high pressure exists on the poles.

c) From these high pressure polar regions, cold winds flow to areas at about 60-65° latitudes in both the hemispheres.

d) The winds flow in NE direction in the northern hemisphere and in SE direction in the southern hemisphere.

Mountain winds

a) Blows from mountain up slope to base

b) Occurs during night time

c) Cooling of air close to slope takes place

d) Adiabatic heating decreases this phenomenon

e) Also known as 'Katabalic winds'

Valley winds

a) Blow from valley base to up slope.

b) Occurs during day time

c) Over heating of air adjacent to slope takes place

d) Adiabatic cooling decreases this phenomenon

e) Also known as 'Anabatic winds'

Sea breeze

During the daytime, more so in summer, land is heated more than the adjacent body of water. As a result warmed air over the land expands producing an area of low pressure. The isobaric surfaces bend upward as a result of which the cooler air starts moving across the coast line from sea to land. This is the ‘Sea breeze; or ‘On shore breeze’.

Land breeze

At night because of nocturnal radiation land is colder than adjacent sea and the pressure gradient is directed from land to sea. There is a gentle flow of wind from land to sea. This ‘off-share’ wind is called ‘Land breeze’.

Sl.	Sea Breeze	Land Breeze
1.	Occurs in day time	Occurs in night time
2.	Flows from sea	Flows from land
3.	Have more moisture than land breeze	Do not have more moisture
4.	Occurrence depends on topography of Of coast to greater extent	Occurrence depends on on topography of land to little extent
5.	Modifies weather on hot summer afternoon	Produces cooler winters and warmer summers
6.	Stronger than land breeze	Weaker than sea breeze

Effect of wind on crop plants

1) Transports heat in either sensible or latent heat form from lower to higher altitudes

2) Wind affects the plant directly by increasing transpiration and the intake of CO_2 and also causes several types of mechanical damage.

3) Wind helps in pollination and dispersal of seeds.

4) Light and gentle winds are helpful for cleaning the agricultural produce.

5) Hot dry winds frequently do much damage to vegetation in the growing crops by promoting excessive water loss.

6) Wind has powerful effect on humidity.

7) Long, continued warm, dry winds injured blossoms by evaporating the secretion of the stigma.

8) Provides moisture which is necessary for precipitation

9) Wind prevents frost by disrupting atmospheric inversion

10) Causes soil erosion

Wind speed in different season

Winds represent air in motion. The primary cause of all winds is regional differences in temperature, producing regional differences in pressure. When these pressure differences persist for several hours, the rotation of the earth modifies the direction of motion, till the winds blow along lines of equal pressure. Wind direction and speed are modified frequently due to seasonal variation in solar radiation and differential heating of the earth's surface.

Wind Speed

The winds are generally measured over level, open terrain at 3 meters above ground. Yet, a general idea of the distribution of the mean daily wind speed, on an annual basis as well as on a monthly basis, would be useful. The mean daily wind speed is the value obtained by averaging the wind speed (irrespective of direction) for a whole day. This averaged for all the days of a month is the mean daily wind speed for that month. The daily values averaged for all the 365 days of the year is the annual mean daily wind speed.

Wind Direction

Winds are always named after the direction they come from. Thus, a wind from the south, blowing towards north is called south wind. The wind vane is an instrument used to find out the direction of the wind. Windward refers to the direction wind comes from, and leeward refers to the direction it blows to. When a wind blows more frequently from one direction than from any other, it is called a prevailing wind.

South West Monsoon wind direction

During South West Monsoon period of June to September, the westerly winds prevail on the west of Kerala and south winds on the west of northern Circars, Orissa and Bengal. During April and May the region of high temperature is shifted to north viz., upper Sind, lower Punjab and Western Rajasthan. This area becomes the minimum barometric pressure area to which monsoon winds are directed.

North East Monsoon wind direction

During North East Monsoon period of October to December, on account of the increase in barometric pressure in Northern India, there is a shift in the barometric pressure to the South East and North Easterly winds begin to flow on the eastern coast, by the end of September. These changes bring on heavy and continue rainfall to the Southern and South Eastern India.

Winter Rainfall

It is restricted more to Northern India and is received in the form of snow on the hills and as rains in the plains of Punjab, Rajasthan and central India. Western disturbance is a dominant factor for rainfall during these months in northwestern India.

Summer Rainfall

The summer Rainfall is received from March to May as local storms. It is mostly received in the South East of Peninsular and in Bengal. Western India does not generally receive these rains.

CLOUDS

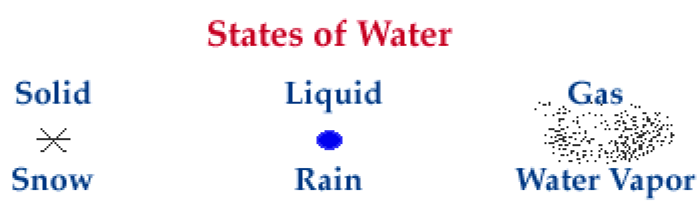
CLOUDS

"An aggregation of minute drops of water suspended in the air at higher altitudes" is called as cloud. A cloud is a visible aggregate of tiny water droplets and/or ice crystals suspended in the atmosphere and can exist in a variety of shapes and sizes. Some clouds are accompanied by precipitation; rain, snow, hail, sleet, even freezing rain. Clouds can occur at any level of the atmosphere wherever there is sufficient moisture to allow condensation to take place. The layer of the atmosphere where almost all cloud exists is the troposphere, although the tops of some severe thunderstorms occasionally pierce the tropopause.

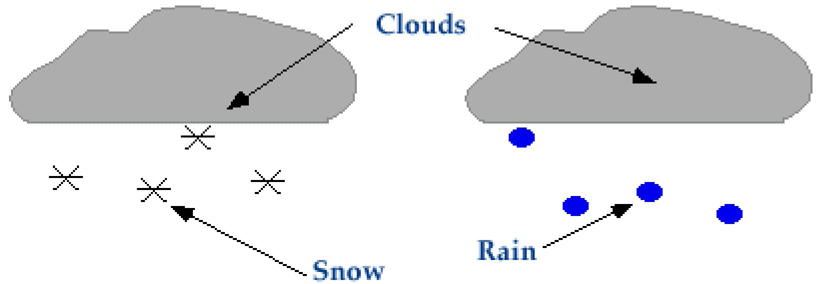
A cloud can be defined as hydrometeor consisting of minute particles of liquid water or ice, or of both, suspended in the free air and usually not touching the ground. It may also include larger particles of liquid water or ice as well as non-aqueous or solid particles such as those present in fumes, smoke or dust.

DEVELOPMENT OF CLOUDS

Water is known to exist in three different states; as a solid, liquid or gas.



Clouds, snow, and rain are all made of up of some form of water. A cloud is comprised of tiny water droplets and/or ice crystals, a snowflake is an aggregate of many ice crystals, and rain is just liquid water.



All of these are made of some form of water.

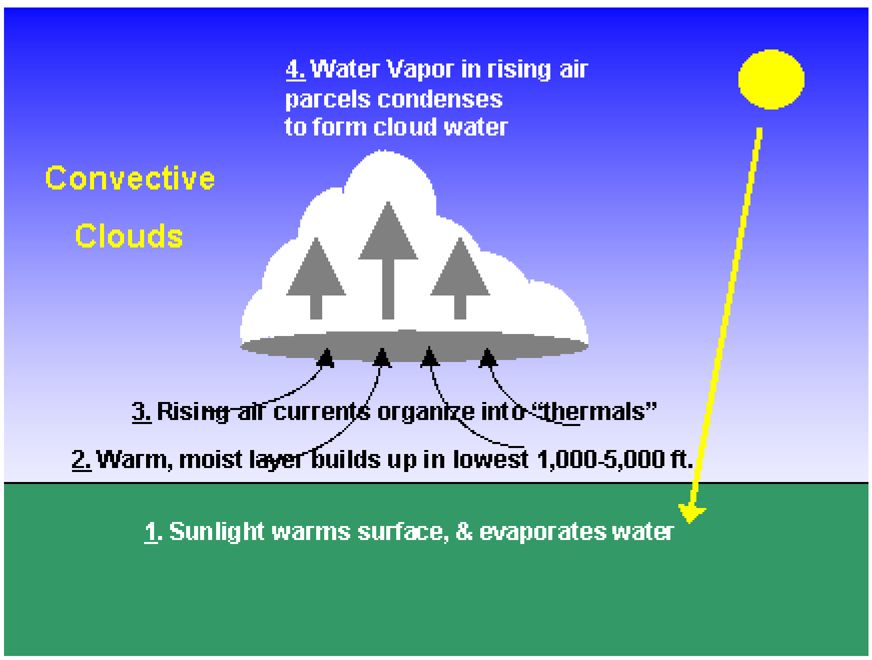
Water existing as a gas is called water vapor. When referring to the amount of moisture in the air, we are actually referring to the amount of water vapor. If the air is described as "moist", that means the air contains large amounts of water vapor. Moisture is a necessary ingredient for the production of clouds and precipitation

All clouds are a form of water. Clouds are condensed atmospheric moisture in the form of minute water droplets or ice crystals. The creation of a cloud begins at ground level. The sun heats the earth's surface, the warm ground heats the air, which rises. The air contains variable amounts of water, as vapor, that has evaporated from bodies of water and plants. Air at ground level is denser than air higher up, and as the warm air rises, it expands and becomes less dense.

Air rises for three main reasons

- Sunshine – heat from the sun or warm ground warms the air and makes it lighter. It therefore rises into the sky.
- The terrain – air may rise as it is forced upwards due to changes in the terrain (landscape). This often occurs when wind blows air either over mountains, or over cliffs onto land from the sea.
- A front – air can also rise at a weather front. At cold fronts, cold air is pushed under warm air, forcing it upwards and at a warm front, warm moist air is forced up and over the cold air.

Expansion cools the air and as the air cools, the water vapor that is present in the air, condenses into tiny microscopic droplets. Cloud formation depends on how much water is in the atmosphere, the temperature, the air current, and topography. If there is no water, no clouds can form. If condensation occurs below the freezing point, the cloud is made of ice crystals. Warm and cold air fronts, as well as topography can control how air rises. Clouds that form during vigorous uplift of air have a tall, stacked appearance and clouds formed by gentle uplift of air currents have a flat or stratified appearance. One can make short-term forecasts by observing clouds, as any change in the way a cloud looks indicates a change in the weather.



After cloud droplets (or ice crystals) form, then what happens to them? One of two things. Either they collide with each other and grow by joining together to such a large size that they fall to the ground as rain or snow, or they evaporate and change back into water vapor. It is estimated that, on average, about one-half of all cloud material eventually falls to the Earth as precipitation, while the other half re-evaporates back into water vapor.

DROP SIZE AND CLOUD APPEARANCE

The smaller the drops in a cloud the brighter the tops appear (and the darker the bases). Smaller droplets scatter more sunlight, while large drops allow more sunlight to pass through. This explains why the heavily raining part of a shower cloud or thunderstorm is usually brighter than just the cloudy part. The cloud droplets have combined into large raindrops, which allow more sunlight to pass through them.

CLOUD CLASSIFICATION

A) A scheme of distinguishing and grouping clouds according to their appearance, and, where possible, to their process of formation.

The one in general use, based on a classification system introduced by Luke Howard in 1803, is that adopted by the World Meteorological Organization and published in the International Cloud Atlas (1956). This classification is based on the determination:

1) genera - the main characteristic forms of clouds

2) species - the peculiarities in shape and differences in internal structure of clouds

3) varieties - special characteristics of arrangement and transparency of clouds

4) supplementary features and accessory clouds - appended and associated minor cloud forms and

5) mother-clouds - the origin of clouds if formed from other clouds.

- The ten cloud genera are cirrus, cirrocumulus, cirrostratus, altocumulus, altostratus, nimbostratus, stratocumulus, stratus, cumulus, and cumulonimbus.
- The fourteen cloud species are fibratus, uncinus, spissatus, castellanus, floccus, stratiform, nebulosus, lenticularis, fractus, humilis, mediocris, congestus, calvus, and capillatus.
- The nine cloud varieties are intortus, vertebratus, undulatus, radiatus, lacunosus, duplicatus, translucidus, perlucidus, and opacus.
- The nine supplementary features and accessory clouds are incus, mamma, virga, praecipitatio, arcus, tuba, pileus, velum, and pannus. (Note: Although these are Latin

words, it is proper convention to use only the singular endings, e.g., more than one cirrus cloud is cirrus, not cirri.)

B). A scheme of classifying clouds according to their usual altitudes.

Three classes are distinguished: high, middle, and low. High clouds include cirrus, cirrocumulus, cirrostratus, occasionally altostratus, and the tops of cumulonimbus. The middle clouds are altocumulus, altostratus, nimbostratus and portions of cumulus and cumulonimbus. The low clouds are stratocumulus, stratus and most cumulus and cumulonimbus bases, and sometimes nimbostratus.

C) A scheme of classifying clouds according to their particulate composition, namely, water clouds, ice-crystal clouds, and mixed clouds.

The first are composed entirely of water droplets (ordinary and/or supercooled), the second entirely of ice crystals, and the third a combination of the first two. Of the cloud genera, only cirrostratus and cirrus are always ice-crystal clouds; cirrocumulus can also be mixed; and only cumulonimbus is always mixed. Altostratus is nearly always mixed, but can occasionally be water. All the rest of the genera are usually water clouds, occasionally mixed; altocumulus, cumulus, nimbostratus, and stratocumulus.

WMO cloud classification

The World Meteorological Organisation (WMO) classified the clouds according to their height and appearance into 10 categories. From the height, clouds are grouped into 4 categories (viz., family A, B, C and D) as stated below and there are sub- categories in each of these main categories.

The 4 clouds families, which are in different heights of the troposphere are

High level clouds (altitudes of 5-13 km)

Medium level clouds (2-7 km)

Low level clouds (0-2 km) and

Clouds with large vertical extending (0-13 km)

Family A

The clouds in this category are high. The mean lower level is 7 kilometers and the mean upper level is 12 kilometers in tropics and sub-tropics. In this family there are three sub-categories.

1. Cirrus (Ci)

- In these clouds ice crystals are present.
- Looks like wispy and feathery. Delicate, desist, white fibrous, and silky appearance.
- Sun rays pass through these clouds and sunshine without shadow.
- Does not produce precipitation.

2. Cirrocumulus (Cc)

- Like cirrus clouds ice crystals are present in these clouds also.
- Looks like rippled sand or waves of the sea shore.
- White globular masses, transparent with no shading effect.
- Meckerel sky.

3. Cirrostratus (Cs)

- ❖ Like the above two clouds ice crystals are present in these clouds also.
- ❖ Looks like whitish veil and covers the entire sky with milky white appearance.
- ❖ Produces “Halo”.

CIRRUS AND CIRROSTRATUS

Cirrus clouds are higher level clouds that develop in filaments or patches. They are virtually brilliant white attributed to their ice crystal composition. However, they lack in contrast between the top and base. They occur in flat sheets with a low height to base ratio and are usually isolated with large breaks of sky. Cirrus also vary dramatically in 'shape' or patterns they portray but these represent the fluctuating wind flow at that level both in the horizontal and vertical direction.

Cirrostratus represent clouds that are more widespread than cirrus but containing some similar features. Like cirrus, they are brilliant white and lack in contrast. Sunlight can pass through cirrostratus but this again depends on the varying thickness of the clouds.

Both cirrus and cirrostratus clouds vary in thickness. The sun can easily be observed through both types of clouds although the intensity of light that is observed depends on the thickness of their layers. In their thickest form, cirrus and cirrostratus will allow a similar intensity of light to pass through to that of thin altostratus. They do not only develop in one complete layer. It may be difficult to observe because of the lack of contrast but these clouds can consist of several thin layers.

Cirrus and cirrostratus tend to move in the direction of the wind at that level which differ to that at the surface. The most common direction of motion of these clouds are from a westerly direction. This varies with factors such as the latitude, weather conditions and time of the year. Their apparent velocities are relatively slow as compared to lower clouds.

Both cirrus and cirrostratus can occur in conjunction with any of the other cloud types. Obviously, all the lower and middle level clouds will obscure the view of the higher level clouds, appear to move faster and appear less defined. They can only be observed above other clouds when breaks in the clouds occur. Any type of higher level clouds can develop simultaneously.

Cirrus clouds tend to develop on days with fine weather and lighter winds at the surface. cirrostratus can develop on days with light winds but normally increasing in strength. Although both cirrus and cirrostratus tend to develop in fine weather conditions, they also acts as a sign of approaching changes in the weather conditions. Such changes could include any of the various types of cold front situations, thunderstorms or developing and advancing troughs of low pressure, normally with preceding cloud masses.

Except in the latter case, cirrus and cirrostratus will typically precede any other types of clouds as part of a cloud band. In fact cirrus normally precedes cirrostratus. Nevertheless, the higher level clouds will persist until the actual change in the weather occurs. The higher clouds can develop from a few hours up to a few days before an actual change in the weather conditions occurs. They may develop during one afternoon and dissipate but redevelop the next day and so on until the actual change occurs. If the amount of moisture in the lower layers of the atmosphere increases, other lower clouds may also develop changing the appearance of the cirrus or the cirrostratus clouds as well as partially or totally hiding them from view. The same situation occurs in the case where cirrus develop ahead of thunderstorms. Cirrus normally precede cirrostratus which are then followed by the anvil of the approaching thunderstorm. In fact, cirrus and cirrostratus in this case are the remnants downwind of the weakening anvil.

Both cirrus and cirrostratus can develop and persist after a change has passed through a certain location. In this situation, cloud will decrease within a few hours up to a few days following the change. If it persists for longer periods, a jet stream cloud mass may be involved.

Another situation where cirrus and cirrostratus can be observed is when lower cloud breaks or clears during days with showers or rain. This case is far less common but can indicate a few situations. The higher clouds may be the remnants of the cloud mass that produced the actual wet weather. They can also be developing ahead of other cloud masses associated with another system, leading to the situation already discussed above. It all depends on the weather situation at that time but the observation of the movement of the higher level clouds can be critical in determining what weather may follow.

Cirrus generally does not produce precipitation except when it results from dissipating thunderstorms. Precipitation from such cirrus usually consists of larger droplets and the cloud normally dissipates and vanishes completely. cirrostratus does not produce precipitation.

Cirrus and cirrostratus can develop and persist at any time of the day despite the perception that it tends to occur during the day. This perception arises because it is much easier to observe cirrus during the day as compared to night time. The background darkness and the fact that the stars can easily be observed through cirrus and cirrostratus as thin layers allows them to camouflage from the view of the observer.

Cirrocumulus

Cirrocumulus is a higher level cloud that is brilliant white but with a spotty appearance created by the many small turrets. The turrets indicate vertical turbulence within the cloud. Despite this spotty appearance, cirrocumulus contains many features associated with cirrostratus discussed above. It moves in directions similar to that of the other higher clouds.

This cloud can develop in conjunction with any other clouds as well as with cirrostratus clouds. In Sydney, cirrocumulus is not as common as the other high clouds and mainly develops during the winter times with west to south westerly air streams. The development of cirrocumulus sometimes occurs in conditions similar to those associated with the development lenticular altocumulus. cirrocumulus clouds do not produce precipitation and are normally associated with fine weather.

Family B

The clouds in this category are middle clouds. Middle level clouds are those clouds that develop in the middle layers of the atmosphere. These clouds are brighter and less fragmented in appearance due to their distance from the ground and the higher composition of ice crystals. Middle level clouds vary in thickness from relatively flat sheets of cloud to a more cumuliform appearance. In fact, the sun (and moon) can be observed through some thin middle level clouds. The mean lower level is 2.5 kilometers and the mean upper level is 7 kilometers in tropics and sub-tropics.

Middle level clouds tend to have apparent speeds slower than the lower level clouds. They move in the direction of the wind at that level which does not necessarily be the same of that at the surface.

In this family there are 2 sub-categories as details below:

1. Altocumulus (Ac)

- In these clouds ice water is present.
- Greyish or bluish globular masses.
- Looks like sheep back and also known as flock clouds or wool packed clouds.

2. Alto-stratus (As)

- In these clouds water and ice are present separately.
- Looks like fibrous veil or sheet and grey or bluish in colour.
- Produces coronos and cast shadow.
- Rain occurs in middle and high latitudes.

Altocumulus

Altocumulus refers to the middle level cloud that exhibit to some extent the features normally associated with cumulus. This includes cumuliform tops and bases that are usually relatively darker than the tops. This cloud type can be widespread or patchy depending on the conditions. It can vary in appearance from broken to smooth, and vary in thickness.

Altocumulus can vary in its apparent movement (speed) depending on the wind and direction at that level. However, since altocumulus (like most other cloud types) represents an ever changing system, an observer must be careful in determining cloud motion. On some days, altocumulus continuously develop as it moves in the direction of the wind. Upstream, more altocumulus may develop giving the impression that the cloud is progressing slower than its actual speed. This process can occasionally create an illusion in terms of direction. Considering an example of altocumulus observed moving to the south east, because of development on the north and north-eastern side of the cloud band, the apparent direction may be more to the east. Altocumulus can develop in more than one layer and also in conjunction with other cloud types. The lower layer will obscure part or all of the higher altocumulus cloud layer. This situation also applies to higher level clouds. Higher level clouds will be obscured by the altocumulus. Lower level clouds, however, will obscure part or all of the altocumulus cloud layer.

ALTOSTRATUS

Altostratus refers to middle level cloud that appears as a flat, smooth dark grey sheet. These clouds are most often observed as large sheets rather than isolated areas. However, in the process of development, altostratus may develop in smaller filaments and rapidly develop to larger sheets. These types of clouds in certain conditions normally indicate an approaching cloud mass associated with a cold front, a trough system or a jet stream.

Altostratus can develop into a thick or thin layer. As a thin layer, the sun can be observed through the cloud. In its thinner form, the developing altostratus can sometimes be confused with approaching cirrostratus. In its thicker form, the sun can only occasionally be observed through the thinner sections if not at all. Obviously, the thicker the altostratus, the darker it becomes. When observed closely, it becomes apparent that altostratus is not just one complete layer but a composition of several thin layers.

Altostratus can produce precipitation. It will normally develop and then thicken. The precipitation is observed as relatively thick dark sections since precipitation cascades are very difficult to observe with the same colour in the background. In this situation, rain will develop as a light shower and gradually increase to showers, light rain or moderate rain.

Family C

The clouds in this category are lower clouds. The height of these clouds extends from ground to upper level of 2.5 kilometers in tropics and sub-tropics. Lower level clouds consist of those clouds in the lower layers of the atmosphere. Because of the relatively low temperatures at this level of the atmosphere, lower level clouds usually reflect lower amounts of light and therefore usually exhibit low contrast. The clouds at this level also appear not as well defined. When observed closely, it is easy to observe the turbulent motions and hence the ever-changing structure.

Being closer to the ground, lower level clouds appear to move or progress faster than other clouds. The clouds generally move in the direction of the wind very similar to the direction of the wind on the ground.

The most efficient method used to recognise lower clouds is when observed in conjunction with other clouds. The lower clouds will obscure part or all the view of the upper level clouds if they pass in between the observer's line of sight. In other words, all the observer can see is the lower clouds as well as parts of the higher level clouds through breaks of the lower clouds. In this family, like high clouds, there are 3 sub-categorises.

1. Strato cumulus (Sc)

- These clouds are composed of water.
- Looks soft and grey, large globular masses and darker than altocumuls.
- Long parallel rolls pushed together or broken masses.
- The air is smooth above these clouds but strong updrafts occur below.

2. Stratus (St)

- These clouds are also composed of water.
- Looks like for as these clouds resemble grayish white sheet covering the entire portion of the sky (cloud near the ground).
- Mainly seen in winter season and occasional drizzle occurs.

3. Nimbostratus (Ns)

- These clouds are composed of water or ice crystals.
- Looks thick dark, grey and uniform layer which reduces the day light effectively.
- Gives steady precipitation.
- Sometimes looks like irregular, broken and shapeless sheet like.

Stratocumulus

Stratocumulus are low clouds that generally move faster than cumulus and are not as well defined in appearance (recall the techniques of observing clouds). They tend to spread more horizontally rather than vertically.

Depending on the weather conditions, stratocumulus can appear like cumulus since stratocumulus can develop from cumulus. They may also appear as large flat areas of low, grey cloud. Sometimes stratocumulus appear in the form of rolling patches of cloud aligned parallel to each other. Stratocumulus can also appear in the form of broken clouds or globules. The sun, moon and generally the sky can be observed through the breaks in broken stratocumulus clouds. Of course, this depends on how large the breaks are, how high the clouds rise and the angle of elevation of the breaks with respect to the observer. This generally applies to all clouds but is more notable with clouds in broken form.

Stratocumulus mostly develop in wind streams moving in the direction of the wind similar to the direction of the wind at the surface. The friction created by the earth causes turbulence in the form of eddies. With sufficient moisture, condensation will occur in the lower layers of the atmosphere visible as clouds. The amount of stratocumulus covering the sky depends on the amount of moisture concentrated at that level of the atmosphere. The speed that the cloud moves varies according to the wind

Stratus

Stratus is defined as low cloud that appears fragmented and thin. It can also occur in the form of a layer or sheet. The sun, moon and generally the sky can usually be observed through stratus clouds, especially at a steep angle of elevation. Stratus lacks the vertical growth of cumulus and stratocumulus, and therefore lacks the contrast. This is more evident when observed as one layer as compared to patchy stratus. Being closest to the ground, stratus clouds normally move fairly rapidly in the direction of the wind depending of course on the wind speed.

❖

Like stratocumulus, stratus develops under several conditions or weather situations. Stratus mostly develop under the influence of wind streams where moisture condenses in the lower layers of the atmosphere. Wind changes during the summer months often lead to the development of stratus as the wind evaporates moisture from the ocean and condensing as turbulence mixes the surface air with the cooler air above. In these conditions, stratus develop in patches and gradually may become widespread forming into stratocumulus.

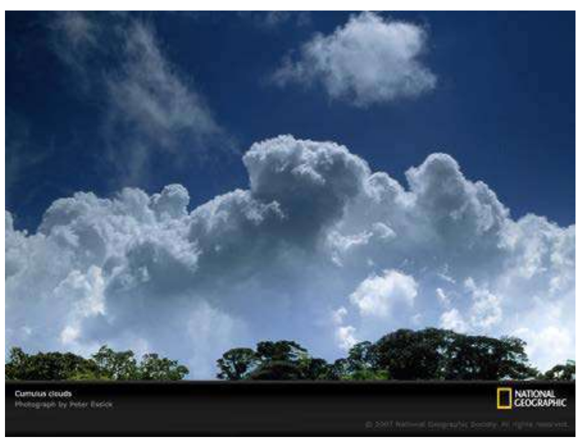
Family D

These clouds form due to vertical development i.e., due to convection. The mean low level is 0.5 and means upper level goes up to 16 kilometers.

In this family two sub-categories are present.

1. Cumulus (Cu)

- ❖ These clouds are composed of water with white majestic appearance with flat base.
- ❖ Irregular dome shaped and looks like cauliflower with wool pack and dark appearance below due to shadow.
- ❖ These clouds usually develop into cumuolo-nimbus clouds with flat base.



2. Cumulonimbus (Cb)

- ❖ The upper levels of these clouds possess ice and water is present at the lower levels.
- ❖ These clouds have thunder head with towering envil top and develop vertically.

- ❖ These clouds produce violent winds, thunder storms, hails and lightening, during summer.

Cumulus

Cumulus are cauliflower-shaped low level clouds with dark bases and bright tops. When observing cumulus, you are actually observing the condensation process of rising thermals or air bubbles at a certain level in the atmosphere known as the condensation level.

The air rising above this level condenses and cloud is observed. Since the height of this level is fairly constant at any particular time, then the bases of cumulus are usually flat.

PRECIPITATION

When cloud particles become too heavy to remain suspended in the air, they fall to the earth as precipitation. Precipitation occurs in a variety of forms; hail, rain, freezing rain, sleet or snow.

Rain

Rain develops when growing cloud droplets become too heavy to remain in the cloud and as a result, fall toward the surface as rain. Rain can also begin as ice crystals that collect each other to form large snowflakes. As the falling snow passes through the freezing level into warmer air, the flakes melt and collapse into rain drops. Rain is precipitation of liquid water particles either in the form of drops having diameter greater than 0.5 mm or in the form of smaller widely scattered drops. When the precipitation process is very active, the lower air is moist and the clouds are very deep, rainfall is in the form of heavy downpour. On occasions, falling raindrops completely evaporate before reaching the ground.

Drizzle: It is fairly uniform precipitation composed of fine drops of water having diameter less than 0.5 mm small and uniform size and seems to be floated in the air, it is referred as drizzle. If the drops in a drizzle completely evaporates before reaching the ground, the condition is referred to as 'mist'.

Hail

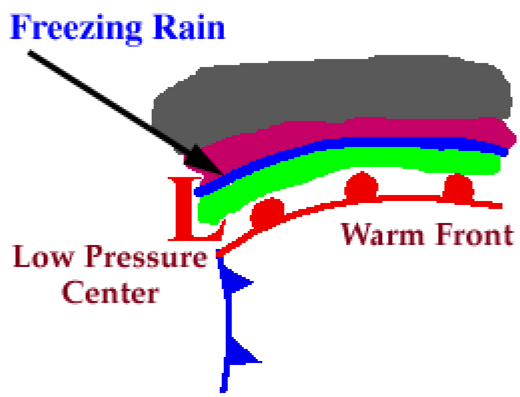
Hail is a large frozen raindrop produced by intense thunderstorms, where snow and rain can coexist in the central updraft. As the snowflakes fall, liquid water freezes onto them forming ice pellets that will continue to grow as more and more droplets are accumulated. Upon reaching the bottom of the cloud, some of the ice pellets are carried by the updraft back up to the top of the storm.

As the ice pellets once again fall through the cloud, another layer of ice is added and the hail stone grows even larger. Typically the stronger the updraft, the more times a hail stone repeats this cycle and consequently, the larger it grows. Once the hail stone becomes too heavy to be supported by the updraft, it falls out of the cloud toward the surface. The hail stone reaches the ground as ice since it is not in the warm air below the thunderstorm long enough to melt before reaching the ground.

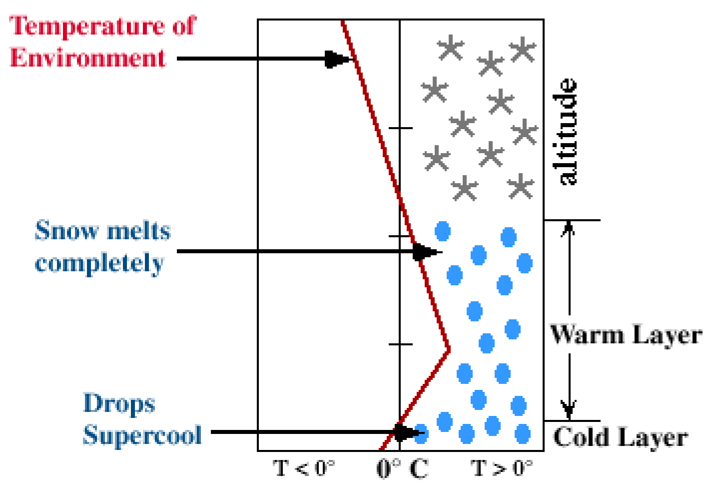
Freezing rain

Supercooled droplets freezing on impact

Ice storms can be the most devastating of winter weather phenomena and are often the cause of automobile accidents, power outages and personal injury. Ice storms result from the accumulation of freezing rain, which is rain that becomes supercooled and freezes upon impact with cold surfaces. Freezing rain is most commonly found in a narrow band on the cold side of a warm front, where surface temperatures are at or just below freezing.



The diagram below shows a typical temperature profile for freezing rain with the red line indicating the atmosphere's temperature at any given altitude. The vertical line in the center of the diagram is the freezing line. Temperatures to the left of this line are below freezing, while temperatures to the right are above freezing.



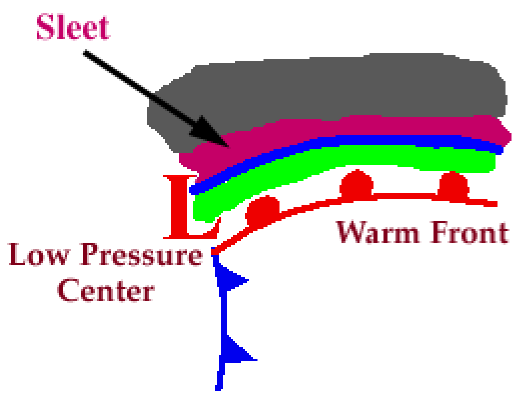
Freezing rain develops as falling snow encounters a layer of warm air deep enough for the snow to completely melt and become rain. As the rain continues to fall, it passes through a thin layer of cold air just above the surface and cools to a temperature below freezing. However, the drops themselves do not freeze, a phenomena called supercooling (or forming "supercooled drops"). When the supercooled drops strike the frozen ground (power lines, or tree branches), they instantly freeze, forming a thin film of ice, hence freezing rain.

Snow

It is the precipitation of white and opaque grains of ice. Snow is the precipitation of solid water mainly in the form of branched hexagonal crystals of stars. In winter, when temperatures are below freezing in the whole atmosphere, the ice crystals falling from the Altostratus do not melt and reach the ground as snow.

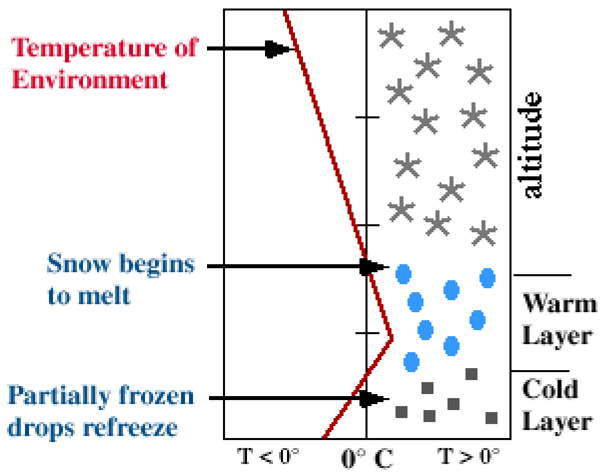
Sleet - frozen raindrops that bounce on impact with the ground

Progressing further ahead of the warm front, surface temperatures continue to decrease and the freezing rain eventually changes over to sleet. Areas of sleet are located on the colder side (typically north) of the freezing rain band.

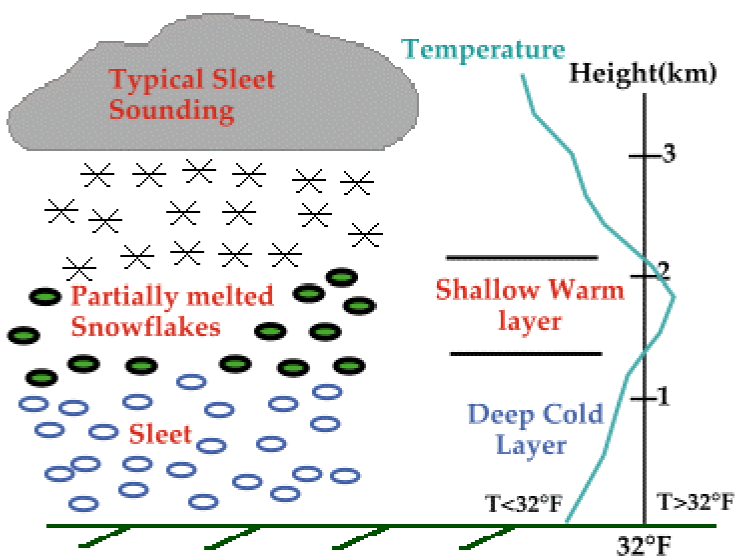


It refers to precipitation in the form of a mixture of rain and snow. It consists of small pellets of transparent ice, 5 mm or less in diameter. It refers to a frozen rain that forms when rain falling to the earth passing through a layer of cold air and freezes. This happens when temperature is very low. It is not commonly seen in India expect high ranges, that too in winter, in extreme north and northeast India.

Sleet is less prevalent than freezing rain and is defined as frozen raindrops that bounce on impact with the ground or other objects. The diagram below shows a typical temperature profile for sleet with the red line indicating the atmosphere's temperature at any given altitude. The vertical line in the center of the diagram is the freezing line. Temperatures to the left of this line are below freezing, while temperatures to the right are above freezing.

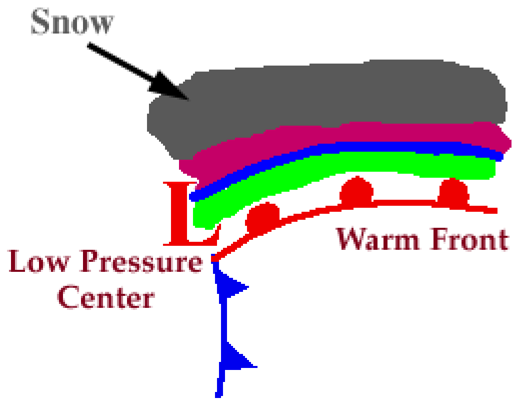


Sleet is more difficult to forecast than freezing rain because it develops under more specialized atmospheric conditions. It is very similar to freezing rain in that it causes surfaces to become very slick, but is different because its easily visible.

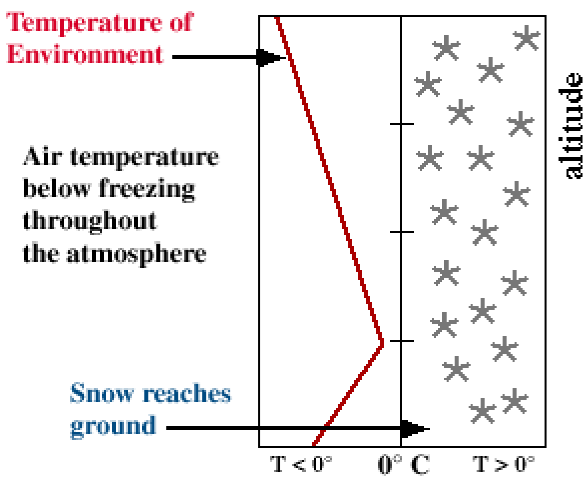


Snow - an aggregate of ice crystals

Progressing even further away from the warm front, surface temperatures continue to decrease and the sleet changes over to snow.



Snowflakes are simply aggregates of ice crystals that collect to each other as they fall toward the surface. The diagram below shows a typical temperature profile for snow with the red line indicating the atmosphere's temperature at any given altitude. The vertical line in the center of the diagram is the freezing line. Temperatures to the left of this line are below freezing, while temperatures to the right are above freezing.



Since the snowflakes do not pass through a layer of air warm enough to cause them to melt, they remain intact and reach the ground as snow.

Hail

Precipitation of small pieces of ice with diameter ranging from 5 to 50 mm or something more is known as hail. Hailstorms are frequent in tropics. In India, the period from March to May offers the ideal condition for hailstorms. It is the most dreaded and destructive form of precipitation produced in thunderstorms or cumulonimbus clouds.

Isohyets

Isohyets are the lines connecting various locations, having an equal amount of precipitation.

WEATHER ABERRATIONS

DROUGHT

The term drought can be defined by several ways.

1. The condition under which crops fail to mature because of insufficient supply of water through rains.
2. The situation in which the amount of water required for transpiration and evaporation by crop plants in a defined area exceeds the amount of available moisture in the soil.
3. A situation of no precipitation in a rainy season for more than 15 days continuously. Such length of non-rainy days can also be called as dry spells.

Classification of Drought

Droughts are broadly divided into 3 categories based on the nature of impact and spatial extent.

i. Meteorological Drought

If annual rainfall is significantly short of certain level (75 per cent) of the climatologically expected normal rainfall over a wide area, then the situation is called meteorological drought. In every state each region receives certain amount of normal rainfall. This is the basis for planning the cropping pattern of that region or area.

ii. Hydrological drought

This is a situation in which the hydrological resources like streams, rivers, reservoirs, lakes, wells etc dry up because of marked depletion of surface water. The ground water table also depletes. The industry, power generation and other income generating major sources are affected. If Meteorological drought is significantly prolonged, the hydrological drought sets in.

iii. Agricultural Drought

This is a situation, which is a result of inadequate rainfall and followed by soil moisture deficit. As a result, the soil moisture falls short to meet the demands of the crops during its growth. Since, the soil moisture available to a crops insufficient, it affects growth and finally results in the reduction of yield. This is further classified as early season drought, mid season drought and late season drought.

Flood

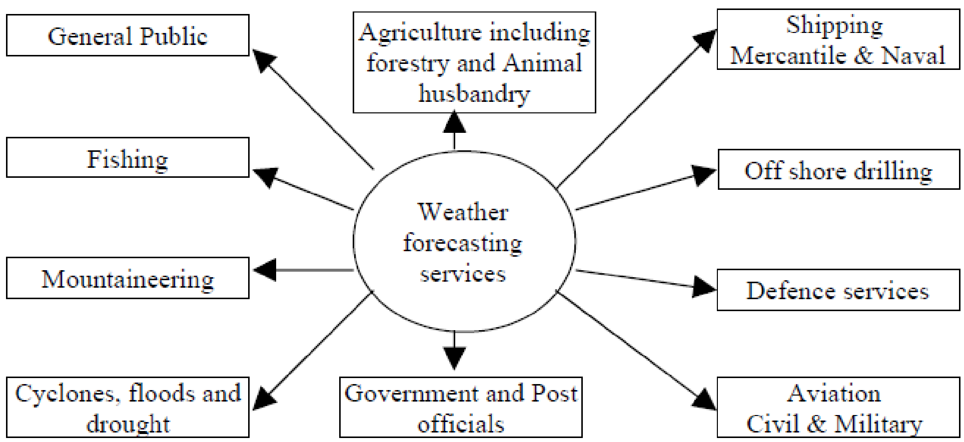
Years in which actual rainfall is 'above' the normal by twice the mean deviation or more is defined as years of floods or excessive rainfall. Like droughts, the definition of floods also varies one situation to another and form one region to other. Some of the flood years characterized based on the spatial damage due to high and intense rainfall in India are as follows.

India: 1878,1872,1917,1933,1942,1956,1959,1961,1970,1975,1983,1988.

WEATHER FORECASTING

Climatic normals

The climatic normals are the average value of 30 years of a particular weather element. The period may be week, month and year. The crop distribution, production and productivity depend on the climatic normals of a place. If the crops are selected for cultivation based on the optimum climatic requirements it is likely that the crop production can be maximized.



Weather forecast

The prediction of weather for the next few days to follow. The Figure below depicts different weather forecasting services normally practiced in a country.

NEED / IMPORTANCE OF FORECAST

- Basically weather has many social and economic impacts in a place.
- Among different factors that influence crop production, weather plays a decisive role as
- aberrations in it alone explains up to 50 per cent variations in crop production
- The rainfall is the most important among the required forecast, which decides the crop
- production in a region and ultimately the country’s economy.

- The planning for moisture conservation under weak monsoon condition and for flood relief under strong monsoon condition is important in a region.
- A reliable weather forecasting when disseminated appropriately will pave way for the effective sustainability.
- One can minimize the damage, which may be caused directly or indirectly by unfavourable weather.
- The recurring crop losses can be minimized if reliable forecast on incidence of pest and
- diseases is given timely based on weather variables.
- Help in holding the food grain prices in check through buffer stock operations. This means that in good monsoon years when prices fall, the government may step in and buy and in bad years when price tend to rise, it may unload a part of what it had purchased.
- Judicious use of water can be planned in a region depending up on the forecast.

Type of weather forecast

Types of forecast	Validity period	Main users	Predictions
1. Short range a) Now casting	Up to 72 hours 0-2 hours	Farmers marine Agencies, general public	Rainfall distribution, heavy rainfall, heat and cold wave conditions, thunder storms etc.
b) Very short range	0-12 hours		
2. Medium range	Beyond 3 days and upto 10 days	Farmers	Occurrence of rainfall, temperature.
3. Long range	Beyond 10 days upto a month and a season.	Planners	This forecasting is provided for Indian monsoon rainfall. The out looks are usually expressed in the form of expected deviation from normal condition.

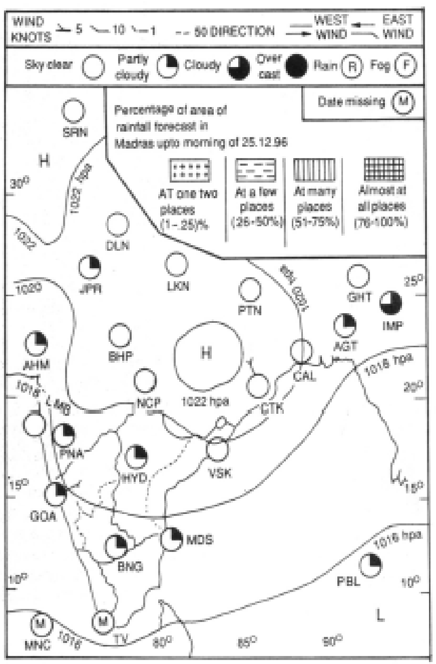
Synoptic charts

An enormous volume of meteorological data is being collected from all over the world continuously round the clock through various telecommunication channels. To assess, assimilate and analyse the vast data, they have to be suitably presented. For this purpose, the observations are plotted on maps instandard weather codes. These maps are called 'Synoptic maps or charts'. Synoptic charts display the weather conditions at a specified time over a large geographical area. The surface synoptic charts plotted for different synoptic hours (00, 03, 06, 09, 12, 15, 18, 21 UTC) depict the distribution of pressure, temperature, dew point, clouds, winds, present and past weather. In place of GMT, UTC (Universal Time Co-ordinate) is used. The upper air charts are also prepared at the standard pressure levels of the atmosphere (different heights) of the atmosphere wherein the pressure, wind and temperature are plotted. The surface charts together with the upper air charts provide a composite three-dimensional weather picture pertaining to a given time. Thus it gives a birds eye view of the state of atmosphere at a time over a large area and is a important tool used by operational meteorologists and scientists. The surface synoptic charts are the most used charts. It contains the maximum number of observations with the largest number of parameters plotted and often forms the base on which the pressure level charts are built up. The pattern of the pressure distribution is brought out by drawing isobars, troughs, ridges, lows, highs, depressions, cyclones, cols, fronts and discontinuities. These systems are clearly marked and labeled using appropriate symbols and colours. In synoptic charts different weather phenomena and atmospheric characters are marked with different symbols as mentioned below.

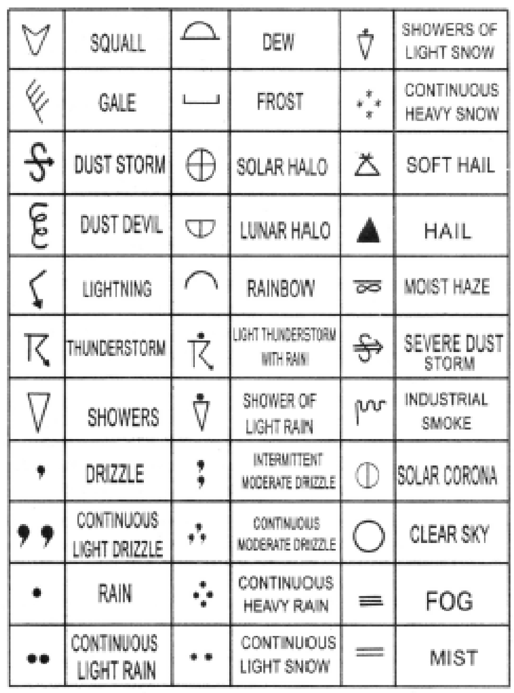
S.No	Symbols	Weather element/character/phenomenon

	Narrow black lines	Isobars
	Numbers at ends of isobars	Pressure values in hPa
	Shading	Precipitation
	Arrows	Wind direction
	Feathers in the arrows	Wind velocity
	Small circles with shading	Amount of clouds

In addition to the above, different symbols are used for recording weather phenomena.



Sample daily weather report



SYMBOLS FOR RECORDING WEATHER PHENOMENA

Weather calendar

In order to provide the farmers with an efficient weather service, it is essential that the weather forecaster should be familiar with the crops that are grown in a particular agroclimatic zone. The type of forewarnings to be given depend on the stages of the crop. In case of farmers, they should become familiar with weather bulletins and learn how to interpret. To meet the above requirement, the detailed information collected from the agricultural departments has been condensed by the IMD and presented in a pictorial form known as crop weather calendar. This calendar has three parts as follows.

a) Bottom part

b) Middle part

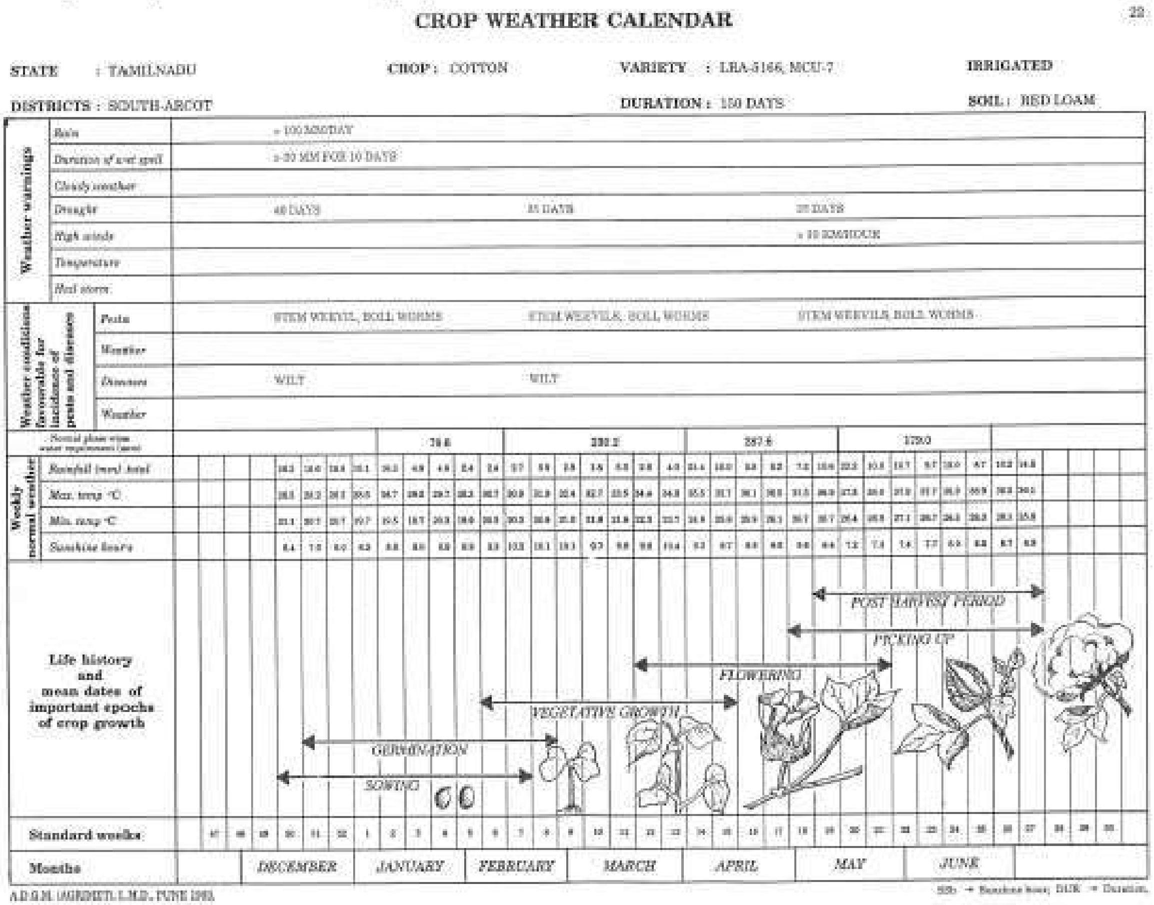
c) Top part

a) Bottom part provides the activities related to crop or information related to phenological stages of the crop and the months.

b) Middle part gives information regarding normal weather condition required for active crop growth. It is divided into different sections according to rainfall, rainy days, minimum temperature, maximum temperature, pan evaporation and sunshine hours.

c) Top part gives information related to the weather abnormalities or to take precautionary measures. Top part is divided into different sections according to dry spell length, high wind, heavy rainfall and cloudy weather.

Sample crop weather calendar prepared for cotton in Tamilnadu for South Arcot district



WEATHER NORMALS FOR AGRICULTURAL CROPS

Sl. No.	Crops	Optimum Temperature ° C		Day length	Rainfall (mm)	Altitude above MSL (m)
		Germi nation	Growth stage			
1	Rice	Min 10 ° C	22-25 (flowering) 20-21(grain formn) 20-25(ripening)		1500	<3000
2	Maize	35-44 ° C				
3	Sorghum	7-10	25-30	Short day		
4	Pearl millet		28-32		400-750	
5	Finger millet				500-1000	
6	Kodo millet				400-500	
7	Wheat	20-22	16-22		250-1800	<3500
8	Barley		12-15 (growth) 30(reproduction)	Long day	400-500	
9	Oats	15-25			380-1140	
10	Ground nut	27-30	24-27		500-1250	
11	Sesame	25-27		Short day	500-650	<1250
12	Castor	20-26		Long day	500-600	<3000
13	Sunflower	20-25			500-700	<2500
14	Rape seed and Mustard	18-25		Long day	300-400	
15	Safflower	15-16	25-30	Day neutral	600-900	
16	Soybean	15-32	30-33		600-650	1200-2000
17	Pigeon pea	20-30				
18	Green gram	15	20-40	Short day	600-1000	
19	Black gram					1500
20	Cow pea	12-15	21-35	Short day	600	
21	Bengal gram		15-25		600-1000	
22	Cotton	18	21-27	Day neutral	500	
23	Jute		27-40	Short day	1500	
24	Tobacco	28	25-35		500-1000	
25	Sugar cane		24-30	Long day	2000-2500	
26	Sugar beet	12-15	22-30	Long day		
27	Potato	18-20	18-20			

WEATHER MODIFICATION – ARTIFICIAL RAIN MAKING AND CLOUD SEEDING

Weather modification refers to willful manipulation of the climate or local weather. Research done in this field goes back to as far as the early 1940s when the US military experimented with cloud seeding to stimulate rain. Today, private corporations have joined the weather modification research effort to protect people, cities and assets from the damage extreme weather brings.

Principles of rainmaking

Clouds are classified into warm and cold clouds based on cloud top temperature. If the cloud temperature is positive these clouds are called warm clouds and if it is negative they are called as cold clouds. The nucleus needed for precipitation differs with type of clouds. Hygroscopic materials are necessary as nucleus for warm clouds

History of Cloud Seeding

Cloud seeding experiments started with the work of a scientist from General Electric named Vincent Schaefer who discovered that ice crystals can induce precipitation. Since ice crystals are difficult to transport and spread over an area, silver iodide, a compound with similar properties, was used as a substitute. The experiments continued until the 1970's when the program was shelved because of lack of usable results.

Cloud seeding

Cloud seeding is one of the tools to mitigate the effects of drought. It is defined as a process in which the precipitation is encouraged by injecting artificial condensation nuclei through aircrafts or suitable mechanism to induce rain from rain bearing cloud. The raindrops are several times heavier than cloud droplets. These mechanisms are different for cold and warm clouds.

How it Works

Cloud seeding involves the use of water-absorbent materials to encourage the formation of clouds and rain so that there could be increased crop production in areas where there's little water. This practice has already been implemented in some areas like Texas and Utah, though not without its share of controversies. The effectiveness of cloud seeding cannot be proven and some worry that it may actually cause harm.

Cloud seeding useful in the following applications

Increasing Precipitation

The most common application of cloud seeding is to increase precipitation, possible with both warm and cold clouds. There are two primary methods employed to stimulate precipitation. One, hygroscopic seeding, affects warm cloud processes. The other, glaciogenic seeding initiates cold cloud processes.

Though occasionally both techniques may be helpful, in most cases one can be utilized more effectively than the other. In addition, either technology can be applied from the surface (ground-based) or from an aircraft. Weather Modification, Inc. can help you decide which method will be most effective.

Augmenting Snowfall

Glaciogenic seeding can also be used to increase precipitation from stratiform and orographic clouds. In such cases, seeding may be accomplished through either ground-based or airborne modes. By increasing snowpack and resultant spring runoff, subsequent water supplies for hydropower are increased. In addition to alleviating the need for alternative costly power supplies, cloud seeding increases the water availability for municipal, recreational, and environmental interests.

Enhancing Rainfall

Efforts to increase rainfall during the warm seasons are typically aimed at convective clouds. While it is theoretically possible to seed such clouds using ground-based equipment, targeting from aircraft is much more efficient and accurate. It is usually possible to affect the cloud through releases of a seeding agent in sub-cloud updrafts, or by dropping the seeding agents directly into the upper regions of the clouds. Warm season glaciogenic seeding is typically applied to treat supercooled cumulus congestus clouds, either by releasing the ice-forming (nucleating) seeding agent in the updraft beneath the actively-growing cumulus, or by dropping the nucleating agent directly into the supercooled cloud top. The seeding agents can produce ice at significantly warmer temperatures than the natural process. This is how glaciogenic seeding gives the treated cloud a head start in producing precipitation.

When clouds do not grow tall and cold enough to produce precipitation through the Bergeron process, it may be possible to stimulate precipitation growth by seeding these warm clouds with hygroscopic seeding agents. This approach can be quite successful through stimulation of the warm cloud precipitation processes. Hygroscopic seeding is normally done from aircraft flying in the sub-cloud updrafts, in order to affect the initial cloud droplet development which occurs in this zone.

Mitigating Hail Damage

Cloud seeding can be used as a tool to help mitigate hail damage and protect crop yields, homes and other property, thus reducing the economic harm from disastrous storm damage. Since hail is itself ice that is produced only by vigorous convective clouds, it is certain that such clouds are cold enough to be amenable to glaciogenic seeding techniques. Hail develops when excess supercooled liquid water develops within strong updrafts. However, if the excess might be induced to freeze into large numbers of small particles rather than much smaller numbers of large particles, the ice that does precipitate may melt during its transit through the warm sub-cloud layer, or if it doesn't it will reach the surface as much smaller, less-damaging, ice.

Dispersing Fog

Another useful application for cloud seeding is the treatment of ground-based clouds, also known as fog. Supercooled fogs, comprised of water droplets at temperatures cold enough to permit ice development, can easily be cleared by glaciogenic seeding. This can be done either from the ground or from airborne application. Your choice between the two will depend on characteristics such as local infrastructure, topography, and wind.

Seeding of cold clouds

This can be achieved by two ways (1. Dry ice seeding and 2. Silver Iodide seeding).

1. Dry ice seeding

- Dry ice (solid carbon-dioxide) has certain specific features. It remains as it is at –80^{o}C and evaporates, but does not melt. Dry ice is heavy and falls rapidly from top of cloud and has no persistent effects due to cloud seeding.
- Aircrafts are commonly used for cloud seeding with dry ice.
- Aircraft flies across the top of a cloud and 0.5 – 1.0 cm dry ice pellets are released in a steady stream.
- While falling through the cloud a sheet of ice crystals is formed.
- From these ice crystals rain occurs.
- This method is not economical as 250 kg of dry ice is required for seeding one cloud. To carry the heavy dry ice over the top of clouds special aircrafts are required, which is an expensive process.

2. Silver Iodide seeding

Minute crystals of silver iodide produced in the form of smoke acts as efficient ice-farming nuclei at temperatures below –5^{-}C. When these nuclei are produced from the ground generators, these particles are fine enough to diffuse with air currents. Silver iodide is the most effective nucleating substance because; its atomic arrangement is similar to that of ice. The time for silver iodide smoke released from ground generator to reach the super cooled clouds was offer some hours, during which it would draft a long way and decay under the sun light. The appropriate procedure for seeding cold clouds would be to release silver iodide smoke into super cooled cloud from an aircraft. In seeding cold clouds silver iodide technique is more useful than dry ice techniques, because, very much less of silver iodide is required per cloud. There is no necessity to fly to the top of the cloud, if area to be covered is large.

Seeding of warm clouds

1) Water drop Technique

Coalescence process is mainly responsible for growth of rain drops in warm cloud. The basic assumption is that the presence of comparatively large water droplets is necessary to initiate the coalescence process. So, water droplets or large hygroscopic nuclei are introduced in to the cloud. Water drops of 25 mm are sprayed from aircraft at the rate of 30 gallons per seeding on warm clouds.

2) Common salt technique

Common salt is a suitable seeding material for seeding warm clouds. It is used either in the form of 10 per cent solution or solid. A mixture of salt and soap avoid practical problems. The spraying is done by power sprayers and air compressors or even from ground generators. The balloon burst technique is also beneficial. In this case gunpowder and sodium chloride are arranged to explode near cloud base dispersing salt particles.

REMOTE SENSING

Remote sensing is defined as the art and science of gathering information about objects or areas from a distance without having physical contact with objects area being investigated.

Uses: Remote sensing techniques are used in agricultural and allied fields.

1. Collection of basic data for monitoring of crop growth
2. Estimating the cropped area
3. Forecasting the crop production
4. Mapping of wastelands
5. Drought monitoring and its assessment
6. Flood mapping and damage assessment
7. Land use/cover mapping and area under forest coverage
8. Soil mapping
9. Assessing soil moisture condition, irrigation, drainage
10. Assessing outbreak of pest and disease
11. Ground water exploration

Remote Sensing platforms:

Three platforms are generally used for remote sensing techniques. They are ground based, air based and satellite based. Infrared thermometer, Spectral radiometer, Pilot-Balloons and Radars are some of the ground based remote sensing tools while aircrafts air based remote sensing tools. Since the ground based and air based platforms are very costly and have limited use, space based satellite technology has become handy for wider application of remote sensing techniques. The digital image processing, using powerful computers, is the key tool for analyzing and interpretation of remotely sensed data. The advantages of satellite remote sensing are:

Synoptic view ‐ Wide area can be covered by a single image/photo (One scene of Indian Remote Sensing Satellite IRS series cover about 148 x 178 sq.km area).

Receptivity ‐ Can get the data of any area repeatedly (IRS series cover the same area every 16- 22 days).

Coverage ‐ Inaccessible areas like mountains, swampy areas and thick forests are easily covered. Space based remote sensing is the process of obtaining information about the earth from the instruments mounted on the Earth Observation Satellites. The satellites are subdivided into two classes and the types of satellite are as follows:

Polar orbiting satellites

These satellites operate at an altitude between 550 and 1,600 km along an inclined circular plane over the poles. These satellites are used for remote sensing purposes. LANDSAT (USA), SPOT (FRANCE), and IRS (INDIA) are some of the Remote Sensing Satellites.

Geostationary satellite

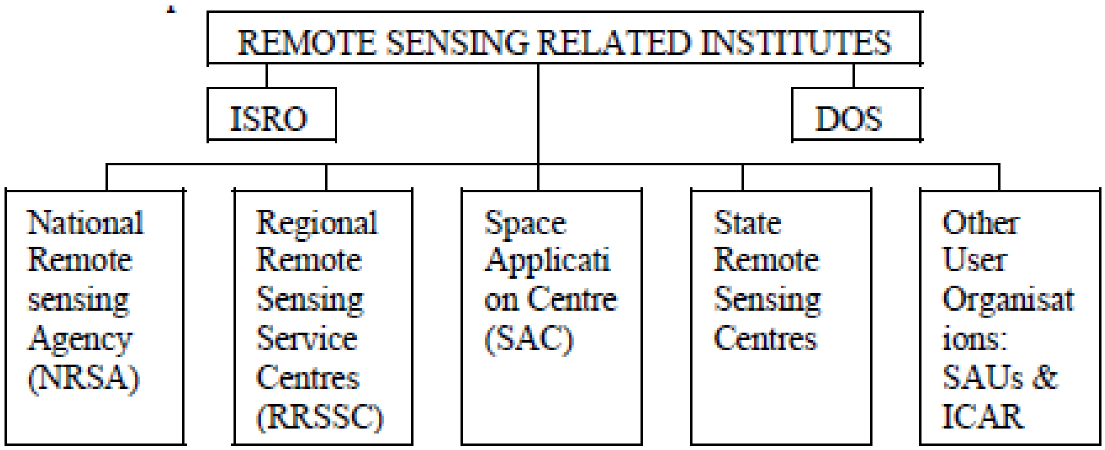
These have orbits around the equator at an altitude of 36,000 km and move with the same speed as the earth so as to view the same area on the earth continuously. They are used for telecommunication and weather forecasting purposes. INSAT series are launched from India for the above purposes. All these satellites have sensors on board operating in the visible and near infrared regions of the electromagnetic spectrum. INSAT-3A was launched on 10th April, 2003.

Role of Remote Sensing in agriculture

Agricultural resources are important renewable dynamic natural resources. In India, agriculture sector alone sustains the livelihood of around 70 percent of the population and contributes nearly 35 percent of the net national product. Increasing agricultural productivity has been the main concern since scope for increasing area under agriculture is rather limited. This demands judicious and optimal management of both land and water resources. Hence, comprehensive and reliable information on land use/cover, forest area, soils, geological information, extent of wastelands, agricultural crops, water resources both surface and underground and hazards/natural calamities like drought and floods is required. Season-wise information on crops, their acreage, vigour and production enables the country to adopt suitable measures to meet shortages, if any, and implement proper support and procurement policies. Remote Sensing systems, having capability of providing regular, synoptic, multi-temporal and multi-spectral coverage of the country, are playing an important role in providing such information. A large number of experiments have been carried out in developing techniques for extracting agriculture related information from ground borne, air borne and space borne data.

Indian Remote Sensing programme:

India, with the experience gained from its experimental remote sensing satellite missions BHASKARA-I and II, has now established satellite based operational remote sensing system in the country with the launch of Indian Remote Sensing Satellite IRS-IA in 1988, followed by IRS-IB (1992), IRS-IC (1995) and IRS-ID (1997). The Department of Space (DOS) / Indian Space Research Organisation (ISRO) as the nodal agency for establishing an operation remote sensing system in the country initiated efforts in the early 1970s for assessing the potentials of remotely sensed data through several means. In order to meet the user requirement of remote sensing data analysis and interpretation, ISRO/DOS has set up a system to launch remote sensing satellites once in three or four years to maintain the continuity in data collection. The remote sensing and some of its related institutes are depicted.



Crop weather modeling

Crop model

It is a representation of a crop through mathematical equations explaining the crops interaction with both above ground and below ground environment. The increase in dry matter of the crop is referred to as growth. The rate of growth of a healthy crop depends on the rate at which radiation is intercepted by foliage and / or on the rate at which water and nutrients are captured by root systems and therefore on the distribution of water and nutrients in the soil profile. The crop development is described in terms of various phenophases through which the crop completes its lifecycle. That is the progress of the crop from seeding or primordial initiation to maturity. Finally the yield of crop stand is expresses as a product of three components, viz., the period over which dry matter is accumulated (the length of the growing period), the mean rate at which dry matter is accumulated and the fraction of dry matter treated as yield when the crop is harvested. It is understood that the crop growth, development and yield depend upon the mean daily temperature (DTT), the length of the day and the amount of solar radiation (PAR) received by the crop.

$$DTT = \frac{\text{Max daily temperature} + \text{Min daily temperature}}{2} - \text{base temperature}$$

Where, DTT = Daily thermal time accumulation.

The time needed for the crop to reach a development stage depends upon temperature measured above a base value (DTT) and for photo periodically sensitive phases such as flowering, the day length above a fixed base. In the absence of stress, the harvest index does not vary much from year to year for a specified cultivar / variety. Therefore, crop weather modeling is based on the principles that govern the development of crop and its growing period based on temperature and / or day length. They are used to quantify the rate of crop growth in terms of radiation interception, water use and nutrient supply which moderate harvest index when the crops experience stress condition. The basic information required to be generated for crop weather modeling includes.

a) Crop phonology in relation to the temperature and day length

b) Water use by the crop during different phenophases of crop growth

c) The relationship between radiation interception, crop water use and total dry matter production

d) Partitioning of dry matter into various plant components as influenced by water and nutrient availability, and

e) The effect of weather parameters on biotic interference to crop growth.

Types of models

a) Statistical models

These models express the relationship between the yield or yield components and the weather parameters. The relationships are measured in a system using statistical techniques. Simple regression techniques explaining weather crop relationships are also considered as models.

b) Mechanistic model

These models explain not only the relationships between the weather parameters and the yield, but explain the relationship of influencing dependent variables.

c) Deterministic models

These models estimate the exact value of the yield or dependent variable. These models also have defined co-efficient.

d) Stochastic models

A probability element is attached to each output. For each set of inputs different outputs are given along with probabilities. These models define the yield or state of dependent variable at a given rate.

e) Dynamic models

Time is included as a variable. Both dependent and independent variables are having values which remain constant over a given period of time. Over a period of time these variables are changing due to change in rate of increment.

f) Static models

Time is not included as a variable. The dependent and independent variables having values remain constant over a given period of time.

g) Simulation models

Computer models in general, are a mathematical representation of a real world system. One of the main goals of crop simulation models is to estimate agricultural production as a function of weather and soil conditions as well as crop management. These models use one or more sets of differential equations over time, normally from planting until harvest maturity or final harvest.

h) Descriptive models

A descriptive model defines the behaviour of a system in a simple manner. The model reflects little or none of the mechanisms that are the causes of phenomena but consists of one or more mathematical equations. An example of such an equation is the one derived from successively measured weights quickly the weight of the crop where no observation was made.

i) Explanatory models

This model consists of quantitative description of the mechanisms and process that cause the behaviour of the system. To create this model, a system is analyzed and its process and mechanisms are quantified separately. The model is built by integrating these descriptions for the entire system. It contains descriptions of distinct processes such as leaf area expansion, tiller production etc. Crop growth is a consequence of these processes.

Climate change and variability

Climate change

Any permanent change in weather phenomena from the normals of a long period average is referred as climate change. Eg. The global temperature has increased by 2.0 to 3.0 C and increase in CO_2 from 180ppm to 350ppm.

Climate variability

The temporal changes in weather phenomena which is part of general circulation of atmosphere and occurs on a yearly basis on a global scale. Climate change and climate variability are the concern of human kind in recent decades all over the world. The recurrent drought and desertification seriously threaten the livelihood of over 1-2 billion people who depend on the land for most of their needs. The weather related disasters viz. drought and floods, ice storms, dust storms, land slides, thunder clouds associated with lightening and forest fires are uncommon over one or other region of the world. The year 1998 was one of the recent weather related disaster years, which caused hurricane house in Central America and floods in China, India and Bangladesh. Canada and New England in the U.S. suffered heavily due to ice storm in January while Turkey, Argentina and Paraguay with floods in June 1998. Vast fires in Siberia burned over three million acres of forests. Human and crop losses are the worst phenomena in such weather disasters, affecting global economy to a considerable extent. The 1997-

’98 El-Nino events, the strongest of the last century is estimated to have affected 110 million people and cost the global economy nearly US $ 100 billion. Statistics compiled from insurance companies for the period 1950-1999. Show that major natural catastrophes which are mainly weather and climate related caused estimated economic losses of US $ 960 billion. Most of the losses were recorded in recent decades. Increase in aerosols due to emission of green house gases including black carbon and chlorofluorocarbons (CFCS), ozone depletion, UV-B filtered radiation, cold and heat waves, global cooling and warming and "human hand" in the form of deforestation and loss of wetlands in the process of imbalanced development for betterment of human kind may be caused factors for climate variability and climate change.

Causes of climatic variability

A. External causes

i) Solar output: An increase in solar output by 0.3%when compared to 1650 -1700AD data.

ii) Orbital variation:

1. Earth orbit varies form almost a complete circle to marked ellipse (Eccentricity).
2. Wobble of earth’s axis (Precession of equinox) 3. Tilt of the earth’s axis of rotation relative to the plane of the orbit varies between 21.8^{o} and 24.4^{o}.

B. Internal causes

i) Changes in the atmospheric composition. Change in the green house gases especially CO2

ii) Land surface changes particularly the afforestation and deforestation

iii) The internal dynamics of southern oscillation - changes in the sea surface temperature in western tropical Pacific (El-Nino/La-Nina) coupled with Southern

Oscillation Index, the Tahiti minus Darwin normalized pressure index leading to the ENSO phenomena

iv) Anthropogenic causes of climate variation in green house gases and aerosols.

Effects of climate change

1. The increase concentration of CO_2 and other green house gases are expected to increase the temperature of the earth.

2. Crop production is weather dependant and any change will have major effects on crop production and productivity.

3. Elevated CO_2 and temperature affects the biological process like respiration, photosynthesis, plant growth, reproduction, water use etc. Depending on the latitude the CO_2 may either offer beneficial effect or may behave otherwise also.

El-Nino and La-Nina

El-Nino is a Spanish word meaning "the boy child" ('Child Christ') because El-Nino occurs around Christmas time each year when the waters off the Peruvian coast warm slightly. In every three to six years, the waters become unusually warm. 'El Ni□' is now used more widely to refer to this abnormal warming of the ocean and the resulting effects on weather. 'El Nino' is often coupled with 'Southern Oscillation' as the acronym ENSO. 'La Nino' is used popularly to signify the opposite of El Nino occurring when the waters of the eastern Pacific are abnormally cold. La Nino episodes are associated with more rainfall over eastern Australia, and continuing drought in Peru. Peruvian meteorologists have objected to term La Nino-the Girl Child-because Christ is not known to have had a sister, and the term anti-ENSO is sometimes preferred. The El-Nino event is due to decrease in atmospheric pressure over the South East Pacific Ocean. At the same time, the atmospheric pressure over Indonesia and North Australia increases. Once the El-Nino event is over, the atmospheric pressure over the above regions swings back. This sea-saw pattern of atmospheric pressure is called Southern Oscillation. Since El-Nino and Southern Oscillation are linked they often termed as ENSO. It is most important one, which represents a tendency for high atmospheric pressure over the Pacific Ocean, represents to be associated with low pressure over the Indian Ocean and vice-versa. A measure of the monsoon low pressure is the Southern Oscillation Index (SOI) represented by the difference in sea level pressure over Tahiti, an Island in South central pacific and Darwin in North Australia, which represents the northern part of the Indian Ocean. The positive SOI denotes high pressure over the central pacific and low over Indonesia, North Australia and Northern Indian Ocean. Above average rainfall is expected over India, India and Indonesia and North Australia if the SOI is positive. Drought or deficit rainfall is expected in the above countries if the SOI is negative, indicating high atmospheric pressure over Indonesia and low in the central pacific.