Rural Management - Agronomy

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Agronomy

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About the Book

Agronomy is a discipline which has agriculture as an integrated part. It deals with the edaphic and climatic factors which include understanding of soil properties, crop interactions with soil factor, fertilizer requirements for the crops, application and timing of fertilizers, insect/pest control as well as pathogenic control in the crops. It deals with the cultivation of crops in order to conserve the natural resources and protect the environment. It covers intercultural practices related to the crops, cereals, pulses, oilseeds, and fibers crops. Along with this, it deals with plant physiology, soil science, plant genetics, meteorology, soil chemistry, plant breeding, soil fertility and environmental science. This book includes all the relevant components of agronomy It includes appropriate crop rotation, irrigation and drainage, classification of soil as well as control of weeds.

This book has the appropriate contents for the students who study agriculture and rural development. It is considered that appropriate agricultural practices need to be learnt by the students. Various fundamental concepts of agriculture such as differences in the terminologies like agriculture and agronomy are mentioned. The process of agricultural evolution with technologies has been narrated. Climate, weather and season have been explained along with their impact on various crops as agriculture is a reflection of edaphic and climatic conditions. The book has explained various agro-climatic zones in order to understand the diversity of agriculture and vividity of crops. Agrometeorological implications have also been explained. This book has mentioned about dryland agriculture as well as rainfed agriculture. Dryland agriculture includes various cropping systems which are suitable for the regions and watershed management as a strategy to deal with dry land agriculture. Apart from this, some lands are swampy, alkaline, acidic and marshy, and which are not suitable for cultivation. That is why they considered waste land. Wasteland management and various techniques are essential to know and they are covered in this book.

There are various resources in agriculture which need proper management techniques. Regarding soil and soil conservation, the discussion and elaboration is in this book. In agronomy water management and irrigation systems are essential to know. Manure and fertilizer management is an essential component of agricultural development which has been covered in this book. There is an account of various crops like cereals, oil seeds, pulses, plantation crops, cash crops and spices and their practices. Post-cultivation practices are mentioned in the book. Farm machinery and tillage operations and their importance have not been ignored either. Seed technology, classification of seeds, seed certification process, seed drying, etc., have been explained.

This book gives a glimpse of modern agricultural techniques such as sustainable agriculture, organic agriculture, post-harvest management, integrated farming system, artificial rain and cloud seeding. There are various techniques which are crucial in the development of agriculture as a part of agronomy. These are hydroponics, roof top farming and remote sensing which are important with the intervention of technology in agriculture for a futuristic vision.

I thank Dr Neelam Yadava, Faculty, TISS Tuljapur for contributing to this book and for her outstanding insights. Also, I would like to thank MGNCRE Team members for extending their extreme support in completing this text book.

Dr W G Prasanna Kumar
Chairman MGNCRE

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Chapter 1 Principles of Agronomy and Agriculture

Introduction

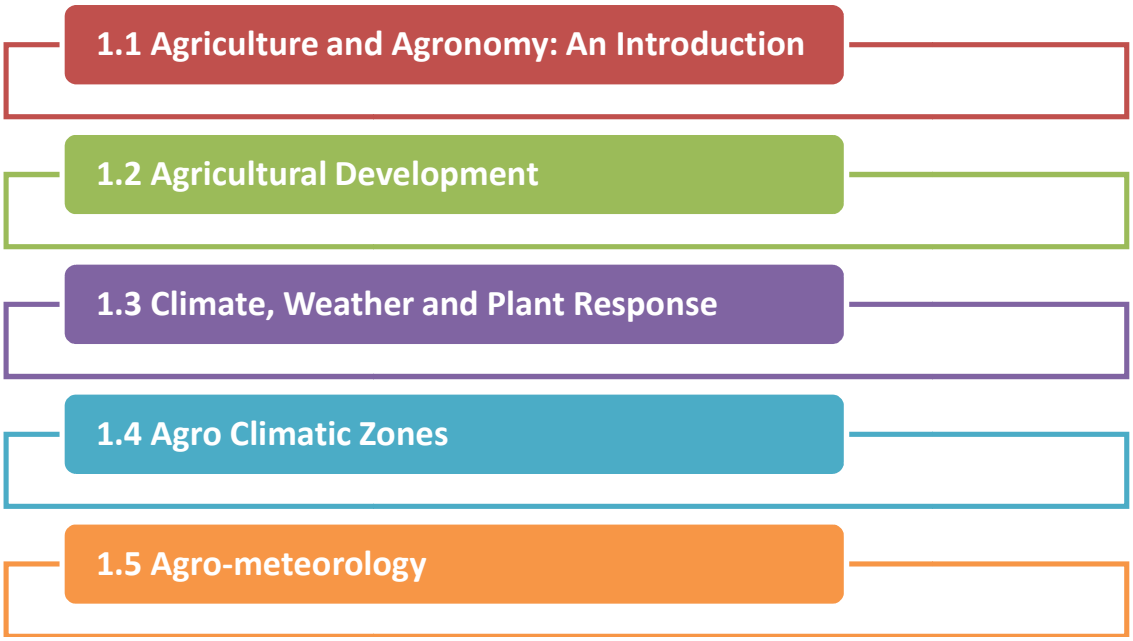
Agriculture is a significant segment for the country's economy as it is not only a source of revenue but a part culture. It not only provides food but also fiber, fuel, furniture, raw materials, etc., for the manufacturing sectors. Agriculture includes multi-dimensions and multidiscipline, which is fast-growing and speedily and rapidly blowout along with the time and territory with the spatial specifications. The Green Revolution is one of the biggest revolutions within the agricultural sector which aimed to achieve food self-sufficiency along with improvement of agricultural practices and agricultural inputs that help to augment the production for the unit of land over time and lower expenditure. The term 'Agriculture' is derived from two Latin terms 'Ager' and 'Cultura'. Ager means land or field and Cultura cultivation. 'Agriculture' has several meanings with various dimensions of crop production and allied aspects such as livestock farming, fisheries and forestry. The meaning of the word agriculture is the farming of land, i.e., a combination of science and art for the production of crops and rearing of livestock for financial determinations. Agriculture as a scientific discipline has made a contribution in the process of enhancement and up-gradation of development of countries. It provides surplus food and exportable commercial crops on a cost-effective basis. Any country seeking to develop its economy has to give a priority to agriculture, particularly scientific agriculture. Whenever agriculture has been undertaken scientifically, it revolutionizes agriculture by way of technological intervention and the green revolution occurred. Another term 'agronomy' comes from two Greek words, i.e., 'agros', which means field and 'nomos', meaning to manage. Agronomy is a discipline that includes both art and science. The art part involves cultivation, creation, production and enhancement of the production of field crops, while the effective practice of all the resources and the decision to apply it appropriately is the science part. Such as strategy to use resources like soil, water, human resources and the relevant factors required for crop production.

Agronomy as a discipline is a combination of three components, viz., (1) crop science, (2) soil science and (3) environmental science, which is an integration of the Soil-Crop-Environmental relationship. There is one more sub-stream of agriculture that can be defined as the sustainable land management system where other aspects are covered such as the production of crops, trees, forest plants and management of allied sectors. Apart from the production of crops, other units of production enhance the sustainability of agriculture like cultural practices of the local population which may involve animal rearing or livestock production. Agrometeorology is the stream under the broader arena of agriculture which is to learning the interrelation amongst meteorological factors with hydrological features on the one side and agriculture on the other. Meteorology is a discipline dealing with weather elements and their connection to agriculture with the impact on crop production.

Objectives

- To explain Agriculture, Agronomy and its streams.
- To examine the scenario of agricultural development with the growth of civilization.
- To examine the difference between climate and weather and their response by the plants.
- To look into the agro-climatic zones in India.
- To study different aspects of Agro-meteorology.

Chapter Structure



1.1. Agriculture and Agronomy

Definition

Agriculture as a discipline did not have a single origin. It originated from various parts across the world and over a period along with different time frames. As a stream, it is an applied science that comprises of various components of crop production which includes horticulture, olericulture and floriculture along with allied sectors like rearing livestock, fish cultivation, forestry, etc. Thus, agriculture is not only an art but science too which includes commercialization of crop production and livestock rearing for economic purposes. Agriculture is an art because it includes scientific knowledge regarding the performance of intercultural operations in the farm. It covers mental and physical involvement skillfully. Mental involvement requires understanding the operations to perform in the farm as per the time, method of ploughing, crop selection, crop rotation, cropping system as per the climatic conditions and soil type accordingly. It is a science because it covers the scientific principles, modern technologies related to interdisciplinary fields like crop breeding, plant pathology, plant protection, economics, etc., to increase productivity and profitability. Plants varieties have been developed with the help of agricultural technologies like hybridization, transgenic crops, pest and disease-resistant varieties, hybrid crops, more fertilizer receptive varieties, management of water-based practices, use of chemicals like herbicides for weed control, bio-control agents, which can fight pests and diseases, etc.

The term agriculture is derived from the Latin word, i.e., Ager+Cultura which means land and its cultivation that reflects that cultivation of land is called agriculture. Agribusiness is described in the Agriculture Act, 1947 as including 'development, common item production, seed production, dairy developing and creatures duplicating and possession, usage of land as snacking land, pasture land, market nurseries, nursery lands and use of land for forests. Agriculture can be defined as agribusiness because of the commercialization of crops to fetch higher net profit and maximum net return after application of factors of production. In the current scenario, agriculture is carried out with the help of information technology which is a technological intervention in agriculture having a multiplier effect on

the profit from agriculture considered commercial. Farming is characterized as a business since it focuses on the most extreme net return through the elements of production and technological up-gradation, which may incorporate administration of land, work, water and investment and use of information on different disciplines for creation of sustenance. In the contemporary situation, agribusiness is marketed to run as a business through technologically upgraded interventions.

Agronomy is a part of agrarian discipline which manages certain practices which follow the management of soil, water and productivity of food crops. In recent times, agronomy is considered as a newer dimension and there is another way to define it as a branch of agricultural sciences, which is related to various approaches that can provide a conducive environment for the crops for higher productivity which includes all the external conditions and influencing factors that affect the life and development of an organism. Agronomy is a discipline with well-defined principles and practices. With the progress of information technology and improved knowledge of plants and their suitable conditions, horticultural practices are adjusted or new practices created for higher efficiency. Agronomy incorporates three segments, i.e., crop science, soil science and environmental science that manage functional viewpoints, i.e., soil-crop-environmental relationship.

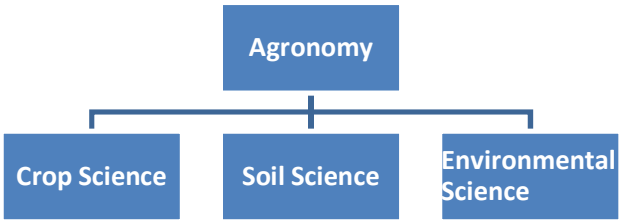


Fig. 1.1 Components of Agronomy

Agriculture: Evolution

Even the most efficient hunting and gathering could hardly support the survival of the human race. The pastoral activities can support the survival of lives, but agriculture alone can support the masses to survive in a sustained manner. During the period 8700 BC to 7700 BC humans domesticated animals and turned as herdsmen. Man first domesticated sheep and later goat. Between the period 7500 BC and 6500 BC, he slowly moved from chasing and assembling to agribusiness. Stone hatchets were used for cutting trees and fire for consuming wood. Grains of oats were drilled with pointed sticks. Cereals grown during this period were wheat, barley, and later rice, maize, and millets. The evolution involved various stages of development in the process of agriculture development. It started from hunting activities and reached up to trade by pastoral activities and crop cultivation. As India was a peaceful nation before agribusiness was begun, advancement of yields and animals occurred simultaneously, prompting different kinds of cultivating frameworks that are currently observed in its various parts.

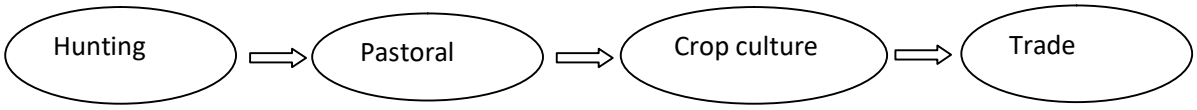


Fig. 1.2 Evolution of Agriculture

With the advent of some activities in various periods, agriculture became transformed from crop culture to scientific agriculture. Evidence from excavations to remote sensing tests show that agriculture is around 10,000 years old. It is also clear that women pioneered agriculture as they observed that plants emerged from seeds. They started cultivating plants from the undomesticated wild flora by digging out

the eatable roots and rhizomes of the plants and suppressed the minor ones for succeeding yields. Animal rearing was also done for meat and skin for clothing.

Shift in Farming Practices

Many farming practices emerged over a period of time. Various cultivation practices were shifting cultivation, subsidiary farming, subsistence farming, mixed farming, advanced farming and so on.

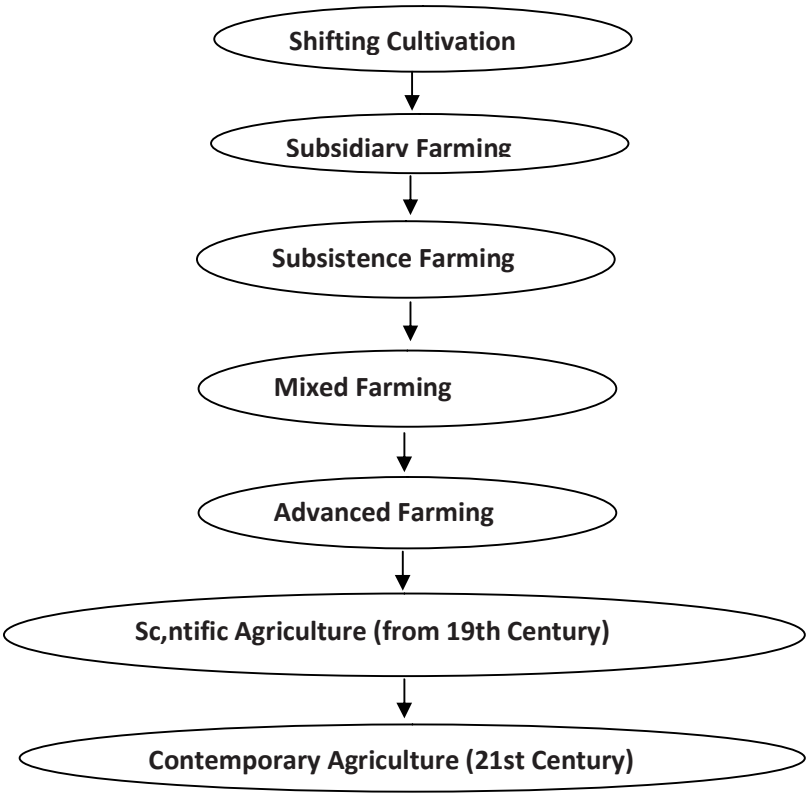


Fig. 1.3 Different farming practices

Shifting Cultivation

This is a primitive form of agriculture in which people cut down the forest, burnt the underneath growth and started cultivating the land. Land was cultivated with the crudest of tools. It had high fertility in the beginning. But as the fertility of land gets down, it is infested with weeds, insects, pests and diseases, and the people move to a new location. They undertake the same operations in the new place, and this type of cut and burn practice of cultivation is called slash and burn cultivation too. In India this practice prevails in various states including North-Eastern states including Assam. In different locations it has different nomenclatures like Jhum cultivation in Assam, Podu in Andhra Pradesh and Odisha, Kumari in Western Ghats, Walra in southeast Rajasthan, Panda Bewar in Madhya Pradesh, and slash and burn in Bihar.

Subsidiary Farming

This is the farming system, which is comparatively not much developed, it may include cultivation, gathering, and hunting. This is the system, where people start the farming practice near to the water availability, the water stream or river as a permanent settlement started in a gregarious manner and underway cultivating in the same piece of land on the regular basis. This system includes a primitive way of farming practice, which may include tools, crops, and cropping methods.

Subsistence Farming

This is also a primitive type of farming practice, while it is comparatively advanced and latest, where agriculture is considered the essential part of the lifespan, which is founded on the principle of "Grow it and eat it" rather than the production of crops for the business purpose to make it commercialize. This farming practice is mainly produced for consumption purposes only not for commercial purposes.

Mixed Farming

This is a more diversified farming system, which includes crop and animal rearing components. The land can be used for both the purpose, initially for cultivation purpose and later used for grazing for animals. The system was a transition stage from the collection of food to the production of food.

Advanced Farming

The upgraded cultivation practice consists of various advanced components like the selection of seeds, organic composting, selection of varieties and seeds, green manuring with legumes, cropping pattern, crop rotation, etc. it includes various practices with advancements like the application of animal cow dung, crop residues as compost, irrigation practices, integrated pest management, nutritional management, rearing of livestock for milk purpose, rearing of bullocks, sheep, goats for various purposes like meat and wool.

Scientific Agriculture (from 19th Century)

Agriculture has been advanced and updated over a period. Till the eighteenth century, agriculture had been modernized with crop rotation, sequencing, organic recycling, exotic crops and animals and farm tools had been used, etc. With the commencement of the nineteenth century, agriculture has been more scientifically dealt with because of research and development (R&D). Fundamental and elementary sciences had been amalgamated for application to agriculture. Agriculture has been considered as multidisciplinary. As a teaching domain, it had laboratories, farm-based activities, research centers, research institutes, teaching and extension activities along with training and demonstration. Several academic works of literature including books and journals were created. Various media and audio-visual aids have spread research findings and disseminated information to the actual users.

Contemporary Agriculture (21st Century)

This is the recent version of agriculture. It is not limited to production. In the contemporary scenario, agriculture is an enterprise rather than just farming. With it are associated commercial ventures such as dairy, poultry, fisheries, piggery, sericulture, apiary, plantation crops, etc. Technological advancements have been added with components like hydrological, mechanical and genetic which have transformed the progress of agriculture. Governmental interventions in terms of subsidy, budgetary support, etc., have been introduced. There are policy interventions like introduction of food preservation and processing, pricing strategies, marketing and distribution mechanism, export and import policies, etc., which have commercialized agriculture rather than confining it to food production. Need-based and region-based agricultural planning has been executed.

Streams of Agriculture

Agriculture is multidisciplinary involving various branches of sciences including functional components such as basic sciences. The pragmatic parts of farming science comprise an investigation of field crops and their administration, i.e., agriculture, which means crop and soil management. Agriculture includes three important spheres, i.e., geoponic cultivation in earth-soil, aeroponic cultivation in air, and hydroponic which is cultivation in water.

Apart from these, there are various streams of agriculture which are agronomy/crop production, horticulture, agricultural engineering, forestry, animal husbandry, fisheries and home science.

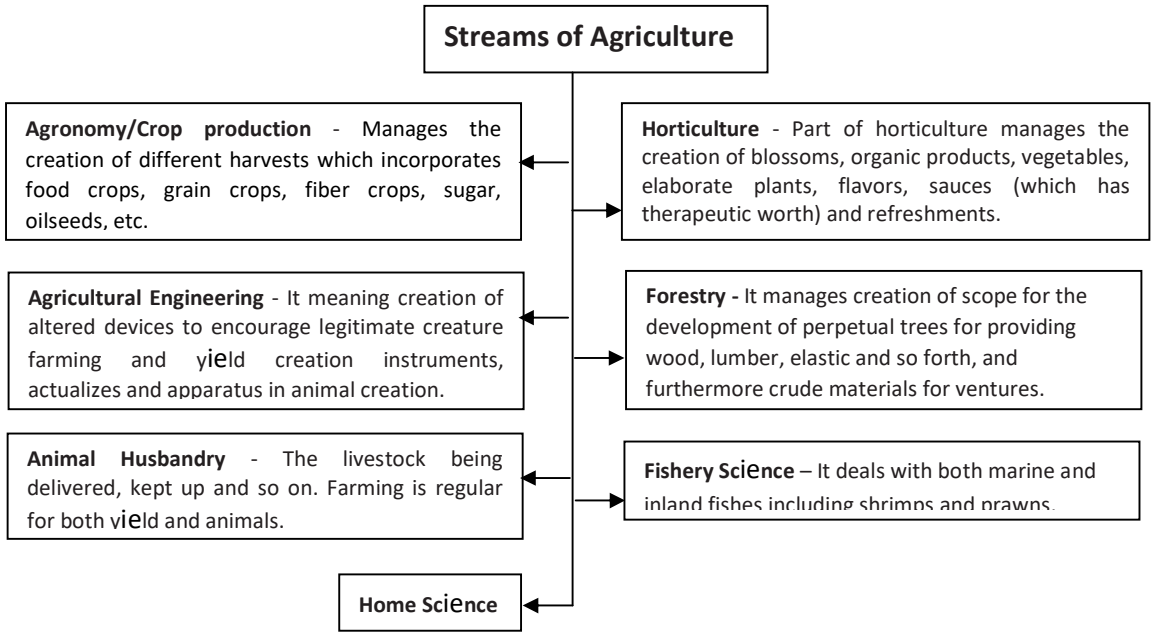


Fig 1.4 Streams of Agriculture

To Do Activity

1. List down various types of the farming system. Discuss the components which make differentiations in all the types of farming.
2. There can be a discussion on various farming practices in various parts of India to understand agriculture in its multidisciplinary and vivid regions.

Agriculture in India: Scope and Importance

With increasing population pressure, the cultivable land is relatively shrinking thereby creating a demand for an intensification of cropping and allied activities. The latter are increasing in two dimensions, i.e., space and time. Along with this, the climate of the country is tropical with an abundant source of solar energy and availability of rivers for irrigation, which is a conducive scenario for crop cultivation. Out of the entire geographical area, i.e., 328.848 million ha, about 143.000 million ha area is under cultivation, and the total cropped area is 179.750 million ha. As per the planning of government and budgetary allocation for agriculture, the proportion of allocation varies because of the regional priorities. Likewise, in the Eighth Five Year Plan about 23% of the national budget was allocated to

agriculture and allied agro-based industries for small sector. India is a major producer of fruits, while the second-largest producer of milk and vegetables in the world. As Indian agriculture is now globalized and advanced, so the production does not aim at food and nutritional security only, but is now concerned with the environmental and sustainability issues as well. The globalized market has now challenged Indian agriculture to make it more competitive and liberalized.

Agriculture as a primary sector of the economy contributes to the GDP approximately 16-19%. It provides livelihood and employment to over 70 per cent of the population. It also contributes to the secondary sectors like providing raw materials for industries such as textiles, silk, sugar, rice, milk products, etc. Rural areas have a big potential for raw material production. Various allied sectors also provide contributions like horticulture, apiary, sericulture, fisheries, etc. Overall, it helps to improve the lives of rural communities.

Scientific Agricultural Development: Indian and Global Scenario

Over a period, agriculture has developed scientifically in a domain of discipline. It started with the domestication of animals and the cultivation of crop species. Cultivation of crops, especially cereals like wheat, rice, barley and millets has been noticed. It has encouraged the settlement of communities, towns and cities across the world. Along with the domestication of cultivable crops, animal rearing has been added.

With the cultivation practices, to make it more refine and productive some agricultural equipment also has been developed like a hoe, harrow, plough, etc. With the advent of time, agriculture and its activities were mainly associated with landholding size, which also causes the politicization of agriculture. On the basis of the land size, farming communities have been divided into large farmers, marginal farmers, medium farmers and small farmers. With the development of the means of communication and transportation, the commercial farming revolution started in agriculture, especially in Europe. At that time, there was a rapid rise in the cities in Western Europe. There was mechanization in agriculture because of the introduction of agricultural tools like reaper, cultivator, thresher, combine harvester, tractor, etc., introduced after the eighteenth century. With the industrial revolution agriculture was integrated with the economic and financial aspects. There were many more technological interventions in agriculture, along with food processing. Various programmes of animal and plant breeding have been introduced with poultry birds breeding to get higher production. Among them are:

- Francis Bacon (1561-1624) introduced the experimentation technique and found that water is the principal requirement for the plant, and if the same crop is cultivated several times, it may reduce fertility of the soil.
- Jean Baptiste Van Helmont (1572-1644) conducted 'willow tree experiment' and also found that water is the only basic requirement for plants.
- Arthur Young (1741-1820) published Annals of Agriculture in the eighteenth century.
- Jean Senebier (1742-1809), a Swiss naturalist, clarified that expansion in the heaviness of plant was because of the utilization of air.
- Theodar Desaussure gave the guidelines of photosynthesis.
- Liebig was a German researcher called 'Father of farming science'. He found that the development of the plant corresponded to the measure of mineral substances accessible in the dirt. This is called 'Liebig's law of least'. Apart from transformation in agriculture at the global level, Indian agriculture also changed in the nineteenth century. From the year 1877 till 1900, there was a decline in the country's population, because of consecutive famines and droughts.

So the British regime introduced various programmes for development. In Lord Curzon's period (1898-1905) the great canal system of Western Punjab was started. At the same time, the Imperial Agricultural Research Institute (IARI) started at Pusa (Bihar) in 1903 which in 1936 was shifted to New Delhi because of an earthquake there. There were several other milestones in agricultural development in India like:

- 1912 - Sugarcane Breeding Institute was set up in Coimbatore.
- 1929 - Imperial Council of Agricultural Research (ICAR) was established in New Delhi afterwards renamed as the Indian Council of Agricultural Research.
- 1960 - First agricultural university was begun at Pantnagar.
- 1965-67 - Green revolution took place in India covering wheat, rice, utilization of manures, development of dams and utilization of pesticides. It brought high yielding varieties (HYVs) of crops.

To Do Activity

Write about the contributions to agriculture made by various scholars or scientists. Much advancement has happened because of the contribution of agricultural scientists. Mention the developments because of contributions in agriculture.

There were various developments in agriculture in the nineteenth century. An experimental station for agriculture was started to deal with the nutrients in Rothamsted, England. The United States Department of Agriculture (USDA) introduced herbicides 2,4-D and agricultural equipment like tractors and combines for harvesting and threshing. International research institutes have started for specific crops. Moreover, other developments took place:

- In 1857 Michigan State University was established for agricultural education at the college level.
- Gregor Mendel discovered the law of heredity in 1866.
- Charles Darwin experimented on cross and self-fertilization in plants in 1876.
- Thomas Malthus in 1898 propounded the Malthusian Theory of Population that people run-out of nourishment because of restricted land and yield capability of harvests.
- Mitscherlich proposed in 1909 the theory of unavoidable losses that increment in development with each progressive expansion of the restricting component is logically lesser and the reaction is curvilinear.
- Wilcox gave in 1929 the opposite yield nitrogen law under which the development or yielding capacity of any harvest plant is contrarily relative to the mean nitrogen content in the dry issue.

Agriculture and Nations' economy - In the current times, agriculture is multidimensional consisting of biotechnology, biochemistry, breeding, crop production, crop protection, etc. Agriculture makes a contribution to the economy promotes industrialization. It not only provides food is also a supplier of raw materials to industries. It contributes in various ways both directly or indirectly by way of employment, national income, human resources to industry, foreign exchange earnings, capital formation and purchasing power to people. There are various disciplines like crop science, soil science, environmental science, plant breeding, post-harvest science, etc., dealing with plant reproduction, crop physiology, organic chemistry, soil science, etc., which incorporates soil composts, fertilizers and so on., and ecological science which incorporate meteorology and yield biology.

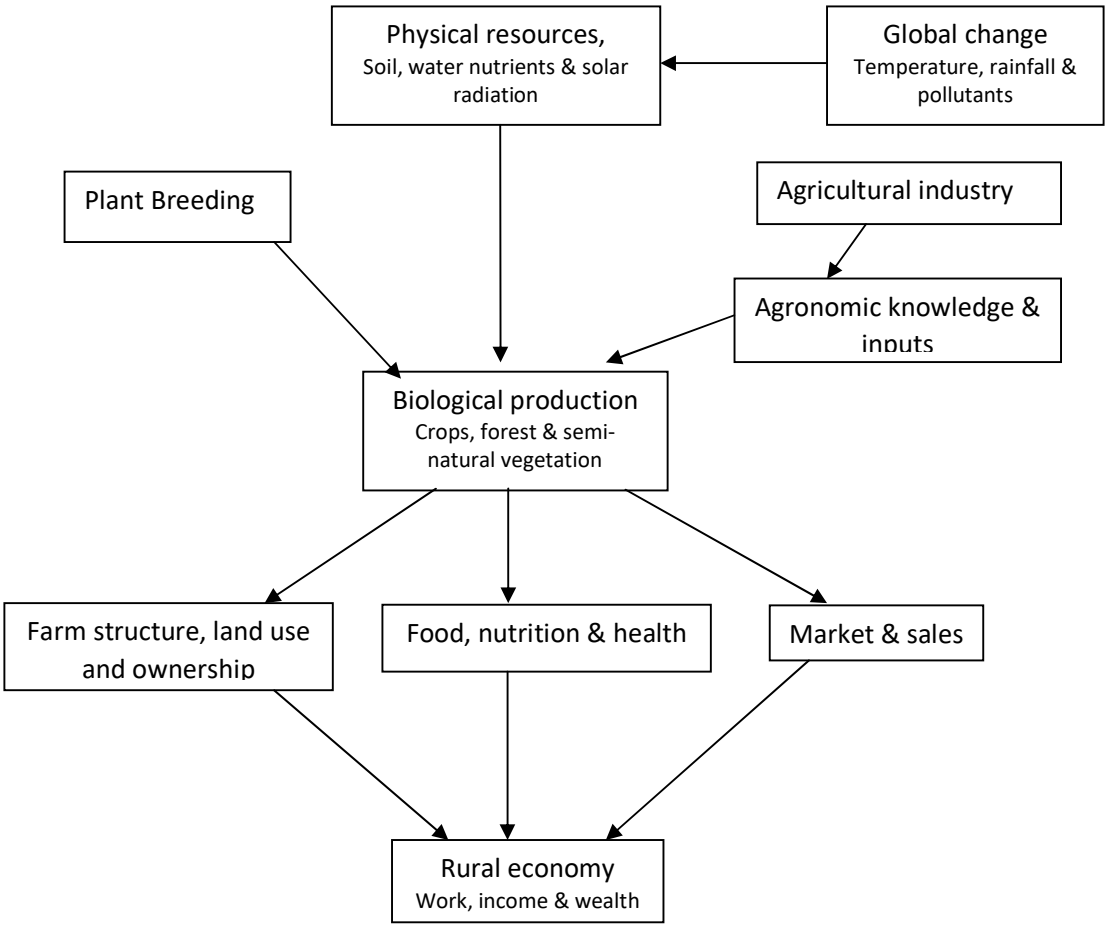


Fig 1.5-Flow diagram of physical, biological, economic and social dimensions of agriculture

Classification of Agronomic Crops

Agronomy is a sub-section of agriculture, which includes the study about the crop production, problems and related issues. It recommends practices for the betterment of crop production, soil management, etc. As per the use of crops and their products, agronomic crops have been divided into various classes. These are cereal crops, millet crops, oilseed crops, pulse crops, forage crops, fiber crops, sugar crops, green manures, medicinal crops and beverage crops. Besides, there are some special purpose crops like contingent crops, cash crops, special crops, cover crops, mulch crops, restorative crops, exhaustive crops, etc.

- Cereal crops are from the Gramineae family where grasses have grown their starch grains which are used as principal food crops such as rice, wheat, maize, barley, etc.
- Millet crops or coarse cereals are a minor food and they have a single cover. For example, foxtail millet, porso millet, etc.
- Oilseed crop seeds are rich in fatty acid and used to get the vegetable oils like mustard seed, soybean, sesame, linseed, safflower, groundnut, etc.
- Pulse crops are of the leguminous group where seeds are used as dal purposes on splitting and are rich in protein like black gram, green gram, peas, etc.
- Forage crops have vegetation and used as fodder for animals such as cowpea, maize, oats, etc.

- Fibre crops are obtained from the seeds of crops such as cotton. Sometimes fibre is obtained from stem like jute, mesta, sun hemp, flax, while at other times from leaf such as agave, pine apple, etc.
- Sugar crops like sugarcane are grown for manufacturing sugar and starch.
- Green manuring crops are grown for enriching the soil nutrients by incorporating plant vegetation into soils. They include sun hemp, dhaincha, cowpea, green gram, etc.
- Narcotic crops are grown to use for stimulation. They are tobacco, cannabis, etc.
- Beverage crops like tea, coffee, cocoa, etc., yield products which are used for mild, permissible and stimulating effects in the liquid form.

Apart from these crops, there are some special purpose agronomic crops like cash crops/contingency crops that replace major crops during natural hazards and are used as the remaining crops. Cash crops are grown for sale for commercial purposes. Mulch crops help to conserve soil moisture. Restorative crops provide a good harvest along with restoration and amelioration of their soil like legumes.

To Do Activity

Enlist various crops along with examples. Try to categorise them with various climatic conditions as well as seasons. Crops can be categorised on the basis of their utility.

1.2 Agricultural Development

Agricultural Status of India

In India the advent of agriculture has been traced since the Neolithic age, i.e., 7500-6500 BC, when civilization and domestication of crops started. Various agricultural practices have been developed like mixed farming, mixed cropping, crop rotation, etc. From the age of traditional knowledge passing through the conventional practices, we have reached the era where ecological consideration becomes a serious concern. There is evidence reflecting the development of agriculture in the Vedas, Buddhist and Jain texts like Krishi-Parashara, Panini's Ashtadhyayi, Kashyapiya-Krishisukt,tc, etc., which contain information related to biodiversity, animal husbandry and agriculture. Rigveda, Kautilya and Manu also describe agriculturists, cattle rearing, economics, commerce, etc. Abundant of information about agriculture is in the Puranas which includes ancient knowledge about agriculture.

Evidence in ancient literature about agriculture:

- There are above 75 species of plants mentioned in the Vedas, above 25 species in Satapatha Bhrahamna and Charkaa Samhita, an Aayurvedic treatise, above 320 species.
- Rigveda (4000 BC) mentions poisonous, non-poisonous, aquatic, terrestrial, domestic and wild creatures.
- There are more than 750 medicinal plant species reported in Susruta (400 BC).
- Puranas notice around 500 types of plants. The study of arbori-agriculture had grown well and archived in Surapala's Vrikshayurveda.
- One section in Agnipurana refers to the treatment of domesticated animals and another to of trees.

Source: History of agricultural development in the world and India. Agriculture heritage – Agriculture in ancient India, eagri.org/eagri50/AGRO101/index.html

Stages of Agricultural Development

Agricultural development has been archeologically categorized into various stages. These are the stone age (around 2,50,000 BC to 3500 BC), bronze age (about 3000 to 1700 BC) and iron age. The stone age is divided into the Paleolithic age, Neolithic age and Mesolithic age. There is evidence for the initiation of growing food and domestication of animals in this age. Herders existed in the Paleolithic and Mesolithic ages, while food producers in the Neolithic age. This period was important because man has started to control the environmental factors and resources, and settlement of villages. Technological and economic progress was made. More refined instruments, pottery for food grain storage, textile weaving, basketry, cultivation of crops and vegetables, and discovery of silk are found in this period. In the bronze age metal, especially copper, was used for the first time. There was an invention of agricultural tools like plough, digging equipment, sowing tools, etc., and irrigation system was developed. The iron age, called Saptasindhava, means land of seven rivers (Sutlej, Beas, Ravi, Chenab, Jhelum, Sindhu and Saraswati). The key feature was the development of agricultural tools, especially sickles, axe, hoes, and plough. Domestication of animals like dogs, goats, sheep, mules, and cattle breeds also took place.

In terms of agricultural technology development, agriculture in India has been broadly divided into five periods, i.e., past history (before 15000 BCE) and Vedic period (1500 BCE-200 BC), early common era (200-1200 CE), late middle ages (1200-1757 CE) and colonial British era (1757-1947 CE). With these categories, agriculture has been developed right from the cultivation and domestication of crops and animals to the development of irrigation systems, water management systems, etc. There was a major development in Indian agriculture in 1871 when the Government of India started the Department of Revenue, Agriculture and Commerce. There were many production-related revolutions from the 1960s which included the Green Revolution, Yellow Revolution (oilseeds in 1986-1990), Operation Flood or White Revolution (for milk in 1970-1996), and Blue Revolution (for fisheries in 1973-2002), etc. There was a National Agricultural Innovation Project launched in 2006 for the end-to-end approach for solving agriculture-related issues.

Table 1.1 Stages of Agricultural Development

Era	Agricultural Development
History (Before 1500 BCE)	Cereal crops like wheat and barley, and sheep and goats domesticated in the Indian subcontinent. Cotton cultivation and drainage system developed.
Vedic period (1500 BCE–200 CE)	Except for wheat and barley (rabi crops), some kharif crops also cultivated, jute cultivation for rope making, domestication of trees, and worshipping of trees like banyan and pipal trees started.
Early Common Era – (200–1200 CE)	In India, especially in Tamil Nadu crops like rice, sugarcane, cotton, coconuts, millets, tamarind, sandalwood, etc., were cultivated. Ploughing, manuring, weeding irrigation, systematic cultivation, water storage, spice trade, especially in cinnamon and black pepper developed.
Late middle ages– (1200–1757 CE)	Water bodies creation/water technology symbolized Arabic and Persian works. Agricultural 'zones', crops like cotton, sugar, and citric fruits in North Africa, Islamic Spain, and in the Middle East of the country.
Colonial British Era (1757–1947 CE)	Water system and waterways on the Sutlej. Agrarian formation extended. Agrarian change because of the broad water system by channels linked Punjab, Narmada valley and Andhra Pradesh.

Indigenous Technical Knowledge (ITK)

Indigenous technical knowledge developed, which is entirely about the information, acquaintance and application, which are grounded on the traditional information and experience, which helps to manage the situation and solve the problems in various issues of life, specifically related to culture. There are some ITK practices performed, followed and practiced.

- In the case of agriculture, soil pulverization is done in summer, especially when land is cultivated, ploughed and left for sunlight which conserves soil moisture, eradicates weeds, consolidates soil erosion, kills eggs of insects and pests, etc. It minimizes the cost of cultivation and expenditure on pesticides, weedicides, etc.
- Coating of cow dung practiced for cotton for easy dibbling of seeds to remove the fuzz. It helps in good germination and pest control.
- Ash mixing with green gram during post-harvest helps to control pest economically.
- In the case of sorghum, the seeds are dipped in cow urine before sowing which increases their germination in drought or less moisture conditions and makes them drought tolerant.
- Treating cotton seeds with red soil helps in their easy dibbling and good germination.
- Rearing of cattle or penning them helps organic manure production which improves soil fertility.
- Cow dung as cow dung cakes used as a fumigant to control rodents economically.
- Castor as a border crop is used in cotton fields which is a trap crop for cotton insects/pests and is economical.
- Coating of red gram with red soil helps pest control, increasing the shelf life of crops as well as easy removal of kernels.

Floricultural Development in India

There is evidence of ornamental trees or plants and their multiple uses in the Mohenjo-Daro and Harappa period (3500–1750 BC). Many trees like pipal (Ficusrel,giosa), neem (Azadirachta Indica), katha (Acacia catechu), etc., were sacred for the people. Many plants were ornamental and used aesthetic purposes like the Ashoka tree (Saracaindica). In the Ashoka van and Panchvati, Asvattha (Ficusbenghalensis) and Aamla (Emblica Officinalis) are also mentioned. Some climbers, scented shrubs and garland flowers like Madhavilata (Hiptagemadhablata), mask-mallow (Hibiscus abelmoschus) and (Hedichiumcoronarium) are also mentioned. Similarly, in the Mahabharata there is a description of the layout of various landscapes, gardens, parks and artificial lakes in Indraprastha city. Kadamb tree (Anthocephalus indicus) is associated with Lord Krishna. In the Buddhist monaster,s and stupas there were gardens. They were found in Nalanda and Taxila. Pipal tree is associated with Gautam Budhha's birth as well as his enlightenment in Gaya. His life is closely associated with trees like Sal (Shorea robusta), Ashoka (Saracaindica) and plaksha (Butea monosperma). Ashoka also developed a roadside plantation of trees in 233 BC, the first king to promote arboriculture and adopted it as a state policy. As per Hindu traditions, lots of ornamental plants are worshiped like the Ashoka (Saracaindica), Padma (Nelumbo nucifera), and tulsi (Ocimum sanctum), papal (Ficusreligiosa) and banyan tree. Various trees and plants are given importance by attaching them to gods and goddesses. Trees make contributions which are mentioned in the Ramayana, Arthshastra, Agni Purana, Matsya Purana, Buddhist literature and Jain literature. In the Mughal period (in 16th and 17th centur,s) and British period (in 18th and 19th centur,s), the contribution of flora and fauna has been recognized.

Medicinal Plants and their Uses

WHO has estimated that almost more than 80 per cent of the population in developing countries is still dependent on traditional medicines or plant-based herbs for their health care and cure. In modern medical science also, more than 25 per cent of the pharmacopeia contains plant-based medicines. In contemporary times, there is a huge demand in the market for plant-based herbs in developed as well

as developing nations. There is now demand for ayurvedic, herbal, non-toxic and natural products without side effects. Due to affordability, they more demand for herbal plants and their drugs. Herbal plants have many uses in pharmaceuticals, nutraceuticals, food supplements and cosmetics. The Ministry of Environment and Forests has found that more than 8000 plant species have medicinal value.

Domestication of Animals and Its Role in Agriculture

Since the Paleolithic period, man started hunting animals for food and clothing. Man started agriculture as well as domesticated animals for its use. Sheep and goats were reared by him in the pre-agricultural phase. Some ruminants like sheep and goats were reared for milk, meat and clothing. Consequently, man recognized the use of goats for milk and meat and of sheep for meat as well as wool. Large ruminants like cows and buffaloes were not domesticated and they were wild animals. But later on the strength and power of large ruminates was recognized for various purposes like work, food, manure, and skin. Before their domestication, ruminates were considered harmful for damaging the fields. There is a belief that making wealth has four requisites, i.e., cattle rearing, trade, commerce and agriculture. In the Ramayana and Mahabharata importance of cattle rearing has been recognized. In different ages also pastoral activities, agriculture and domestication of animals has been valued. In the Mauryan age, the buffalo was recognized as a dairy animal. A female buffalo as valued for milk production, while a male buffalo for draft purposes, ploughing and transport. Domestication of buffaloes was first mentioned in the Indus valley.

There are references about milk production and its processing into various products. In the Mahabharata period milk products like curd, butter, ghee, etc., were prepared in each household. The traditional way of simmering milk at low temperature and heating on cow dung cakes still exists. Regarding animal management, there is evidence from the post-Vedic era that medicines occupied an important place, and Samhitas and Charka were there in 700 BC. When Materia medica was developed, Ayurveda was there as the ancient medicine system of India like Gavyayurveda for cattle, Hastyayurveda for elephants and Ashvayurveda for equines, etc.

Agricultural Development: Voyage

Based on archeological findings, Indian history has five broad phases, viz., Vedic period, golden period, Mughal period, British period and Modern India.

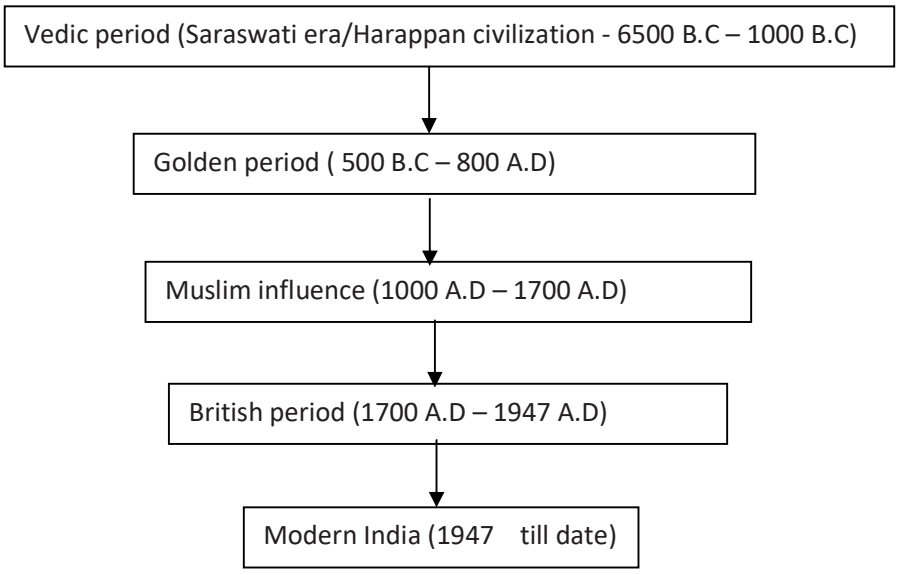


Fig 1.6: Phases of Indian history

In the agricultural development in India various steps have been taken like the Royal Commission has been appointed in 1929 for the examination of the agricultural situation and its impact on the rural economy. In the same year, the Imperial Council of Agricultural Research was recognized under the Societies Registration Act, 1860. Agricultural development is included not only production, food and nutritional security, but also sustainability, environmental concern, profitability and export. India is one of the signatories of the WTO agreement for agricultural marketing wherein it needs to accelerate agriculture development along with research and education. All-India Coordinated Research Project was established as the coordinated project on maize in 1957. Now ICAR has more than 70 coordinated projects of numerous disciplines like crops, livestock, home science, agricultural engineering, etc. ICAR is an autonomous body having rules and bylaws with Director-General as a scientist head with four Deputy Directors-General from crop science, soil science, agronomy animal science, etc. It is responsible for administering research institutes in fields like animal science, fisheries and agriculture. In the history of ICAR, the formation of ARS scientist was one of the major landmarks which started from 1st October 1975.

There are state and central level agricultural universities undertake integrated functioning which includes teaching, research and extension activities. ICAR has supported a programme called Krishi Vigyan Kendra to give training to farmers and in-service extension workers.

To Do Activity

- List down floricultural development in India.
- Find out the hotspots for the biodiversity which includes herbal and medicinal plants. Along with it, write their utility.

1.3 Climate, Weather and Plant Response

Weather, Climate and Season

Weather is the state or situation of the atmosphere at a particular place and at a point of time. There are some short-term changes in the atmospheric conditions of the lower air in terms of wind velocity, air temperature, pressure, solar radiation, precipitation, etc. There may be constant changes, either in hours or in a day. Weather is the physical condition of the atmosphere which changes from place to place and in small regions and from time to time. Agricultural decisions like cropping pattern, crop growth, development, intercultural practices and productivity are affected by weather conditions. In abnormal/adverse weather conditions, cultivators make short term contingency plans. Climate can be defined as the state of general weather of a particular region for a comparatively long duration. Climate is the general condition of the atmosphere of a particular region which varies in a large region, where changes require a larger period (may be years as in the polar region). Agronomic decisions are taken, like crop selection, for certain places based on climatic conditions of the region. Such conditions help in long term planning for agriculture.

The season can be defined as a part of the year during which a specific type of weather prevails. Its duration in may consist of few months, wherein it does not vary much. In the field of agronomy, the importance of season is great as there are crops that have conduciveness according to season. There are three major seasons, i.e., rabi, kharif and zaid.

There is the classification of the season in a temperate region. These are spring, summer and fall or autumn and winter seasons. The spring season is from March to May, which is the first season of the year. It is suitable for the growth of vegetation. The summer season begins in June and continues till August which is the warmest one when plants flourish. The fall and autumn season is from September to November when leaves start turning brown or pale. Winter is the fourth season from December to February. It is the coldest one when most of the trees shed their leaves.

In India according to the India Meteorological Department (IMD), the fourfold classification of seasons is as follows:

a. Kharif season/monsoon/south-west monsoon season from June to September.
b. Post-rainstorm or north-east storm season from October to November.
c. Winter season is from December to February.
d. Zaid or summer or pre-rainstorm season from March to May.

In India three seasons are considered, viz., rabi, kharif and zaid. Post-storm and winter seasons are consolidated and called as rabi season which is from October to February.

Season and Its Specifications

a. Winter season is the cold season with dewfall in the morning. Sometimes cyclonic depressions can have light rains to the north-western region which may be beneficial for some crops except cotton as it sheds the cotton bolls and damages the tobacco leaf quality.
b. Summer season has high temperature, especially in North India. There may be light rains which can be useful for the cultivation of crops for their preparation.
c. South-west Monsoon is the rainy season across the country except for few places of Tamil Nadu which are warm and humid. More than 60 per cent rainfall of the year is received and kharif crops are grown in this period. Crops are grown in the rain-fed areas as they depend on the rainfall.
d. North-east monsoon has high temperature up to October and thereafter gradually starts declining. About 33 percent of the rain fall of the year is received during this season except few places like Tamil Nadu and coastal Andhra Pradesh. In northern India, rabi crops are grown.

To Do Activity

Discuss the classification of agro-climatic zones in India. Map the zones according to the suitability of crops grown in each zone.

Classification of Seasons

There is a particular classification of the season as per some main crops like rice, sugarcane and cotton.

1. Rice is the staple food crop in most of the part of the country, and it is grown in various seasons too as per its different types.
   a. In North India, particularly West Bengal, various kinds of rice are appropriate for various seasons. The rice is developed in various seasons like Aus (May to September), Aman (June-November) and Boro (January to May).
   b. In South India seven seasons change with the locale, i.e., Cauvery delta, Chengalpattu, Tiruvallur, Vellore, Tiruvannamalai, Villupuram, Cuddalore, Tirunelveli, and Kanyakumari. The rice season is in Cauvery Delta Kuruvai (June to September), Early Samba (July-January), Samba (August-January), Late Samba ((September-February), Thaladi (September to February) and

Navarai (December to April). In Tirunelveli and Kanyakumari, the rice assortments of Kar (May to September) and Pishanam (September to January) have diverse occasional appropriateness.

2. Cotton season - There are four cotton assortments in various seasons. These are winter flooded (August-September), summer (February to March), rice decrepit (January to February) and rain-fed cotton (September to October).
3. Sugarcane season - There are four classes of sugarcane crops on the basis of seasonality and irregularity. These are early season (December-January planting), mid-season (February-March planting), late-season (April to May planting) and special season (June-July planting).

Classification of Seasons Agronomically

The seasons have been categorized agronomically where agricultural practices, climatic conditions, soil-plant factors and edaphic factors are involved. It is related to the consumption of water by crops in the equilibrium of precipitation rate as well as water-holding by the soil. The categories are:

a. **Pre-humid period –** In this season evapotranspiration is more than the precipitation period.
b. **Humid period -** Precipitation is higher than the evapotranspiration. There are more vegetative growth and flowering initiated, while the requirement of water is high for the crops. But at the later stage, water requirement and precipitation rate balance, and the water-holding capacity of soil stores the water, as the precipitation is more than the requirement of water for the crop.
c. **Post-Humid period -** This is the later stage of the Humid period, where crops are at their maturity stage. The water stored by soil is used by crops and make use of rainfall water.

Classification of Growing Period

Growing period is categorized into four groups, namely, normal, intermediate, all-year round humid and all-year round dry.

- Normal - This is the season when there is excessive precipitation in the humid period. Crops are grown at the end of the humid period when the precipitation rate is higher than 0.5 PET in the pre-humid period. In semi-arid tropics, this type of growing season is prevalent.
- Intermediate type - Rainfall is less than the PET throughout the year. Crops which are bearable to drought can be grown like pearl millet, castor, etc.
- All year round humid - Rainfall is higher than PET throughout the year which reflects sufficient moisture content in the soil. It is most of the rainfall areas and perennial crops are grown.
- All year round dry – There is very little rainfall, that is, less than 0.5 PET all around the year. These growing seasons are found in extremely arid areas or deserts. Cultivation of crops is not possible in them.

Crop productivity depends on different seasonal and climatic conditions. The duration of the rainy season from the time of sowing to harvesting, quantum and distribution of rains in the humid and pre-humid period, prevention of waterlogging during the humid period owing to excessive rainfall and rainfall during post-humid season affect the soil moisture conditions which impact the productivity and quality of crops.

Factors Affecting Climate

Some factors and components are responsible for climatic conditions. They are latitude, altitude (elevation), precipitation, soil type, nearness to large water bodies, topography and vegetation.

- Latitude is the distance from the equator, from north or south, which is responsible largely to make variations in climatic conditions. Based on it, the climate can be divided into tropical, subtropical, temperate and polar regions.

- Altitude (Elevation) is about the height from the mean sea level (MSL) which is also responsible for variations in climate. Air temperature can decline by 6.5 degrees Celsius per Km from the sea level. Fluctuations in pressure, wind velocity and precipitation are also related to MSL. Altitude can alter the vegetation, soil type and texture as well as crop rotation.
- Precipitation is the factor where the amount and distribution pattern of rainfall decides the nature, type of vegetation and cultivation of crops. Division of regions is based on average rainfall, as follows:

  Arid climatic region - less than 500 mm rainfall
  Semi-arid region- 500 -750 mm rainfall
  Sub-arid climatic region - 750-1000 mm rainfall
  Humid region- More than 1000 mm
- Soil is formed over a period through the process of metamorphosis process which is also modified due to landscape and vegetation. Soil surface colour is also responsible for the rate of absorption, storage capacity and radiation of heat like white-coloured soil surface reflects while black coloured soil absorbs more heat radiation. Because of variations in the absorption rate, there is a variation in air temperature at different regions. Areas of lack soil have hot climate, while that of red soil less.
- Proximity to water bodies influences climatic conditions. Large water bodies such as islands and coastal areas attract more precipitation. Air movements from the earth's surface or water bodies' surface also modify the climate.
- The topography is the surface of landscape or level or uneven surface areas that impact climate. Topography includes the altitude of the region, steepness of the slope and exposure of the slope towards the sunlight as well as wind velocity.
- Vegetation of a region characterizes the climate. Thickness of vegetation is generally more in the tropical region, whereas air temperature and precipitation rate is high. The type of vegetation also symbolizes the type of climate of the region.

Climate Scaling and its Importance

a. **Microclimate -** It is confined to bargain up to the particular highlights of the little zones alongside the physical exercises of the locale takes in the layer of air close by the ground. The particular confined states of air temperature, humidity, wind and radiation in the close by a layer of the character of the ground influences to make varieties in the soil kind, vegetative spread, parts of gradient and soil surface state development. In the control of Agrometeorology, to examine the properties of air close to the ground and surface layer of soil, manages the microclimate.

b. **Meso atmosphere -** It bargains between the size of meso and full-scale atmospheres, and is the investigation of the atmosphere over the generally littler locale which is 10 and 100 Km over.

c. **Macro atmosphere - F**ull-scale atmosphere is the investigation of air over enormous locale of the earth with the bigger size of air movements and exercises which determine climate.

The choices of crops are influenced by the seasonal variations. The latter affect crop selection, growth and development. Weather conditions that prevail during the crop production process right from the sowing till the end will affect both crop production and productivity. Length of the rainy season, amount and frequency of rains during and after the rainy season, wind velocity, solar radiation, spectrum of radiation, characteristics of different wave lengths, air temperature, atmospheric air and its pressure affect crop growth, establishment and yield.

Weather Elements and Effects on Crops

Crop production, climatic, edaphic, biotic, physiographic and socio-economic factors affect plant growth. They are categorized as internal and external factors.

a. Internal factors include genetic or hereditary factors.
b. External factors - environmental factors are:
    i. Climatic-precipitation, air temperature, barometrical weight, moistness, solar radiation, wind speed and air gases.
    ii. Edaphic – soil humidity, soil air, soil temperature, soil mineral issue, soil natural issue and soil creature.
    iii. Biotic - plants and creatures.
    iv. Physiographic.
    v. Socio-economic factors.

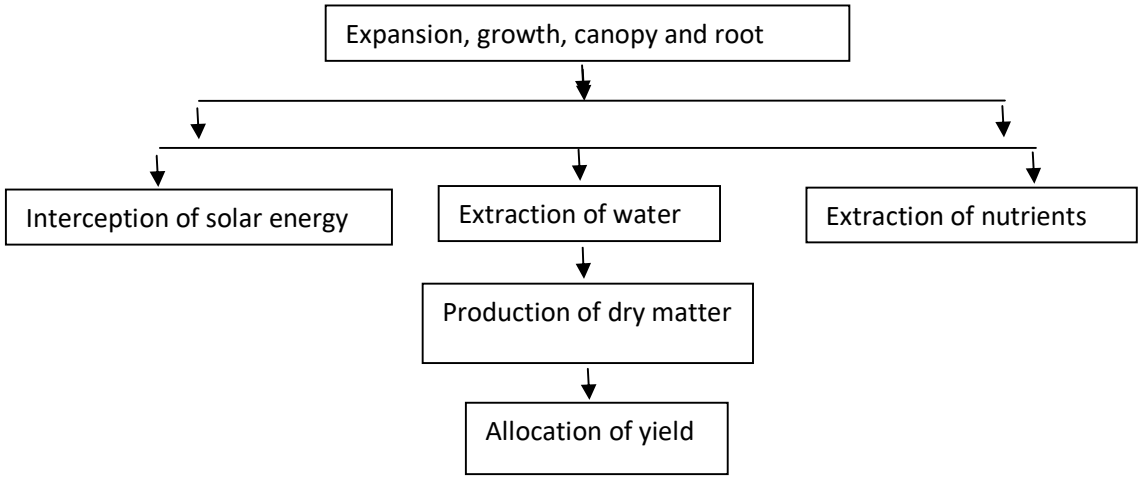


Fig. 1.7: Influence of climate on crops

a. Internal factors, remember genetic variables and the expansion for crop yield or other alluring highlights are worried about the hereditary structure of the plants, similar to high yielding assortments, development, protection from housing, dry season, flood, saltiness, nature of grains (fineness/coarseness), nature of straw (pleasantness/deliciousness), insect pest resistance, etc. These characteristics are not directly governed by environmental/external factors, rather connected with the genetic makeup of the crop.

b. External factors – Environmental factors

i. Climatic factors - They are atmospheric conditions like rainfall, wind velocity, humidity, etc., which regulate almost 50 per cent of crop yield and quality.

- **Precipitation** is the rainfall which includes various forms of water which tumble from the environment like precipitation, day off, mist and dew. Precipitation is the most significant factor which influences the vegetation of any region and decisions related to crop cultivation. In heavy rainfall regions crops like rice, tea, coffee and rubber can grow which require lots of water, while in low rainfall areas dry land farming is done and crops like coarse cereals, millets, etc., are grown. In desert areas grasses, and shrubs can be grown. With all these relations of precipitation and crop yields, the yield is not only related with precipitation completely but the frequency distribution of rainfall is also important.

- **Temperature** is another important factor which is the measure of the intensity of heat energy. The ideal temperature for most crops is between 15 to 40 degrees Celsius. The temperature of any region is governed by the latitude and altitude of the place. Most of the stages of plant growth like germination, growth of the plant, leaf production, expansion and flowering are influenced by temperature. Apart from the physical growth of plants, chemical processes such as diffusion rates of gases and liquids, solubility of different substances in the plant is also governed by the air temperature. There is minimum, maximum and optimum temperature for individual plants which is called basic temperature.
- **Atmospheric humidity (relative Humidity)** is the presence of water in the atmosphere in invisible vapor form and the ratio of the amount of moisture present in the atmosphere to the saturation capacity of the air at a particular temperature. 100% RH means that the entire space is filled with water and no soil evapotranspiration takes place. Therefore, RH regulates the water requirements of crops. The suitable RH for the crop is 40-60%. If RH is > 80%, crops are not well, and more chances of insect/pest infestation are there.
- **Solar radiation** is an essential component for crops from germination to harvesting or even post-harvesting. The physical process of plants, soil and environment takes place in the presence of solar radiation. Photosynthetically Active Radiation (PAR) is essential for the production of carbohydrates and biomass for the plants. With solar radiation several processes take place in crops such as photoperiodism, phototropism and photosensitive.
- **Photoperiodism** is the plant's response to day length. Short day length is solar radiation for less than 12 hours. Crops like rice, sunflower and cotton require short day length, but crops like barley, oat, carrot and cabbage require a long day length or more than 12 hours of radiation. However, day-neutral plants have no influence of day length like tomato and maize.
- **Phototropism** is the response of crop plants to the direction of light such as sunflower.
- **Photosensitive** is the process where crops have season-bound varieties that depend on the quality of light received.
- **Wind velocity** influences crops by carrying the moisture and heat along with supplies of fresh CO2 for the photosynthesis process. A conducive wind movement for most of the crops is 4-6 Km/ hour. Excessive wind velocity can do mechanical damage to the crops like removal of leaves, twigs, etc., in the case of Banana and sugarcane. For pollination of seeds, cleaning produce of farmers and increasing evaporation rate wind velocity has relevance.
- **Atmospheric gases on plant growth** such as Co2, O2, N2, Argon, etc., need to be there in the atmosphere. Co2 for photosynthesis, decomposition of organic material and farm wastes have importance. N2 is one of the major micronutrients to fix the N in the soil, microbes fix the Nitrogen in pulse crops.

ii. **Edaphic factors (soil)** affect plant growth.

- **Soil Moisture** is the principal component for the growth of plants, which plants extracts from the soil, essential for the photosynthesis process. Soil-wise there is a variation in the moisture content as there is more moisture-holding capacity in clay soil than sandy or loamy soils. Moisture content ranges from field capacity and the permanent wilting point is available to the plants. Soil water regulates the chemical as well as biological activities of the soil, which regulates soil temperature, mineralization and nutrient availability.
- **Soil air** is another important factor for the absorption of water by roots, germination of seeds, respiration of roots and microorganisms, decomposition of organic matter and nutrients availability to the plants. Certain crops require more aeration such as potato, cotton, tobacco, tea, linseed and legumes, while others such as rice require low soil aeration and can tolerate even the absence of O2 (waterlogged condition).

- **Soil** temperature influences physical and substance measures in the soil which impact the ingestion of products and solutes, germination of seeds, and development pace of underground aspect of the harvests, for example, custard, yam and so forth. Soil temperature manages the microbial exercises, nutrients availability, etc. For example, rapid growth of most crops may not be possible in low temperature soil (cold soil).
- **Soil mineral matter** is the source for a plant's nutrients such as Ca, Mg, S, Mn, Fe, K, etc., which are derived from the weathering of rocks with different sizes of mineral particles.
- **Soil organic matter** stores all the micronutrients in the plants, increases the soil texture, water holding capacity and releases organic acids during the mineralization process.
- **Soil organisms** are microorganisms that decompose the raw organic matter in the soil and make available the nutrients to the plants and fix N by microbes which are Rhizobium and Azospirillum.
- **Soil reaction (pH)** is the pH level of the soil, i.e., hydrogen ion concentration which affects crop growth. The ideal pH level for most of the crops is neutral, i.e., 7, while less than it is acidic and more than it is alkaline. Low pH soil damages the crops due to high toxicity of Fe and Al and interferes with the availability of plant nutrients for the crops.

iii. **Biotic factors** may have both harmful and beneficial effects.

- **Plants** are the flora which may have complementary or competitive effects on crops. If it is competitive, it can demand micronutrients, moisture, sunlight, etc. For example, competitive relations between weeds and crop plants such as parasites like Striga parasite, weeds on sugarcane crop. While in certain crops, it may have a complementary effect. If cereal crops and legume crops are grown together, they are mutually beneficial to each other in terms of providing nutrients with a consequent high yield called a synergistic effect.
- **Animals** are the soil fauna like protozoa, snails, nematodes and insects help decomposition process, while insects and nematodes damage the crops. Some insects may be useful also such as honey bees and wasps help pollination. Earthworms facilitate aeration and drainage of the soil.

iv. **Physiographic factors** are like topography, the altitude of land such as hilly areas and plains, where precipitation and temperature fluctuate. As there is an increase in altitude, the temperature declines and increases precipitation and wind velocity, which changes the cropping practices, selection of crops and varieties, etc. Steepness of the slope affects the runoff of rainwater and nutrients rich top soils and soil erosion. Exposure of light and wind in the sloppy land may cause poor quality and less crop yield such as in coastal areas and interior pockets.

v. **Socio-economic factors** are the inclination of society towards farming practices which determine the choices of crops for food and fodder requirements for households. Economic conditions affect the selection of inputs and their quality which results in the output. Categories of farmers also affect performance and results.

1.4 Agro-climatic Zones

As per Food and Agriculture Organisation (FAO), an agro-climatic zone is a land unit uniform in respect of air and length of creating period (LGP) which is climatically fitting for a particular extent of harvests and cultivars. There are different groupings of agro-climatic zones given by various criteria, temperature, rainfall, altitude, etc.

In 1989, the Planning Commission of India made a categorization of the entire geographical area of the country into 15 zones/regions based on various agro-climatic phenomena like precipitation, temperature, topography, water resources, cropping pattern, etc.

1. Western Himalayan zone - It covers three sub-zones, i.e., Jammu & Kashmir, Himachal Pradesh and Uttar Pradesh hills which comprise of mountain soil, skeleton soil and hilly brown soil. The land altitude is steep sloppy and undulated terrains. The soil texture is loamy and more prone to erosion.
2. Eastern Himalayan zone - It has high rainfall as well as more vegetation. Sikkim, Arunachal Pradesh, Assam and West Bengal come under it. Shifting or jhum cultivation is practiced. It is a cause of denudation and degradation of land. Due to these reasons, it is prone to floods, droughts, runoffs and soil erosion.
3. The lower Gangetic plains zone has most places having alluvial and fertile soil, but prone to floods. West Bengal comes in this zone.
4. The Upper Gangetic Plains zone is where the water system is performed by tube wells and trenches. In it come 32 areas of UP.
5. Trans-Gangetic Plains Zone incorporates Punjab, Haryana, Delhi and Chandigarh, where a majority of the zones go under the planted zone. It is exceptionally flooded and has groundwater for use.
6. Eastern Plateau and Hills Zone includes the places like eastern MP, Southern part of Bengal, inland Odisha and Maharashtra where the water system is based on channels and tanks. The geography is undulated.
7. Central Plateau and Hills zone incorporates MP, Rajasthan and UP, which contributes almost 33 percent in crop development and gives agricultural yield.
8. Western Plateau and Hills Zone incorporates Maharashtra, MP and Rajasthan with 900 mm normal precipitation. Just 12% is the inundated zone and the waterway is the primary hotspot for the water system.
9. Southern Plateau and Hills Zone incorporates 35 areas of Andhra Pradesh, Karnataka and Tamil Nadu, i.e., semi-parched zone where dry cultivating is done.
10. East Coast Plains and Hills Zone incorporates the area of the east shore of Tamil Nadu, Andhra Pradesh, Odisha and Pondicherry, where the trench is the wellspring of the water system.
11. West Coast Plains and Ghats Region comprises of Tamil Nadu, Goa, Karnataka and Maharashtra with variation in cropping pattern, soil type and precipitation.
12. Gujarat Hills and Plains Zone incorporates 19 locales of Gujarat which are dry and have less downpour. Around 32.5% zone is inundated with tube wells and wells as a wellspring of the water system.
13. Western Dry Zone incorporates Rajasthan where hot sandy desert, lopsided precipitation, sparse vegetation prevail. Starvation and dry spells are common.
14. The Islands Zone comprises of Andaman and Nicobar Islands, and Lakshadweep where rainfall is spread over more than three-fourths of the year. The rainfall is 3000 mm on an average. This zone consists of forests and undulated land.

The agro-climatic classification has logic to maintain sustainability in these regions. There are many more methods of classification which have various criteria. The previous classification method is given by Koeppen and Thronghwaite. The classification is generally based on rainfall, temperature and altitude. The latter affects temperature as well as precipitation rain of the region. According to the National Commission on Agriculture, there are 127 agro-climatic zones. The classification of agro-climatic zone is according to temperature, rainfall and altitude as follows:

Agro-climatic Zones Based on Temperature

Depending on the temperature, there are three agro-climatic zones. They are cool, moderately and warm. Based on variations in temperature in these regions the annual mean air temperature, annual rainfall, altitude and cropping pattern changes.

a. Cool zone - It has temperature below 10 degree Celsius where less than 100 cm rainfall is in northern parts of the north district, 100-200 cm in the southern part of the north district and 280 cm in the extreme north-eastern part of the east district. This zone is 2000 above MSL where above 4000 m there is no cultivable land. This zone is suitable for true potato seeds production (TPS), fruit plants, cabbage, radish, etc.
b. Moderately cool region has temperature ranging from 10-20 degree Celsius, with 300-200 cm rainfall annually. The altitude is 1000-2000 above MSL. It is suitable for crops like maize, wheat, barley, ginger, paddy, oilseed, vegetables, potato, etc. Large cardamoms and oranges are the main cash crops.
c. Warm region has a temperature of more than 20 degrees Celsius with 200-300 cm annual rainfall. The altitude of the region is less than 2000 m. above MSL. The principal crop is paddy, whereas some other crops like maize, ginger, vegetables and pulses are also grown. Sub-tropical fruits like citrus, banana and papaya are also grown.

Agro-climatic Zones based on the Precipitation/Annual Rainfall

Based on annual rainfall, there are four zones. They are very heavy rainfall zone, heavy rainfall zone, moderate rainfall zone and low rainfall zone.

a. Very heavy rainfall zone has more than 300 cm annual rainfall with 12-18 degree Celsius air temperature. The altitude of the region is 1000-2000 m. above MSL. Primary crops are maize, millet peas, wheat, barley and ginger. Large cardamom is the main cash crop.
b. Heavy rainfall zone has 300-200 cm. annual rainfall. Temperature ranges from 13 degrees Celsius to more than 20 degrees Celsius. Principal crops are maize, peas, oilseeds, vegetables, ginger, etc. Large cardamom and orange are the cash crops.
c. Moderate rainfall zone has 200-100 cm. annual rainfall and 7-9-degree Celsius temperature. It is above 2000-3000 m. above MSL. The chief crop is TPS (true potato seed) and other temperate fruits and vegetables like cabbage, radish, etc.
d. Low rainfall zone has less than 100 cm. annual rainfall and around 6.5 degree Celsius temperature. There is no cultivable land above 4000m MSL and only medicinal herbs grow. Potato can grow in North Sikkim.

Agro-climatic Zones based on Altitude

Based on altitude, agro-climatic zones have four categories which have a range of altitude as >3000m, 2000-3000m, 1000-2000m, and <1000m above MSL.

a. The altitude rage above 3000m MSL has less than 1 degree temperature with less than 100-200 cm. annual rainfall. There is perpetual snow and peri-glaciate land with steep side slope , >50%, almost 20-40% area is covered with forests and alpine meadows. The soil is loamy skeleton lithic cryorthents. Land is non-cultivable above 4000m. MSL, but medicinal herbs vegetation is there. Potato can be cultivated in North Sikkim during the summer months.
b. The altitude with 2000-3000m MSL has 10 or less than 10-degree temperature with 200-300 cm. annual rainfall. The physiography of the place is steep side slope with 20-40% area under forest cover. The soil is coarse loamy stone-built udorthents. The climate is suitable to grow TPS, temperate fruits and vegetables.

c. The altitude with 1000-2000 m. above MSL has 10-20 degree temperature and 200-3000 cm. annual rainfall. The soil is fine loamy typic arguidolls. Maize, peas, millet, wheat are barley are grown.
d. The region with 1000m above MSL altitude has more than 20-degree temperature and less than 200 cm. annual rainfall. The main soil type is loamy skeleton cumulus. Paddy is the principal crop. Other crops are maize, ginger, pulses, etc.

Agro-climatic Zones According to ICAR Division

On the advice of state agricultural universities (SAUs), ICAR divided the agro-climatic zones under the National Agricultural Innovations Project (NAIP). The criteria for the classification are annual rainfall, air temperature, cropping pattern and administrative units.

The classification of zones are as follows:

Table 1.2 Classification of zones

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

Source -ICAR, 2007

Agro-Ecological Zone

It is an ecological region which has a particular biological reaction to macroclimate as communicated in vegetation, soil verdure and amphibian framework. It is a unit of land on the world's surface cut out of the agro-climatic region when superimposed on different landform and soil conditions that go about as modifiers of air and length of creating period. According to the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) of ICAR, 20 agroecological regions have been organized. The biological system is named arid environment (3 zones), semiarid ecosystem (5 zones), subhumid ecosystem (6 zones), humid per humid ecosystem (3 zones) and coastal ecosystem (1 zone).

- The arid ecosystem includes three zones- the western Himalayas, western plain kachohh and parts of Kathiawar peninsula and Deccan plateau.
- The semiarid ecosystem includes four zones- northern plain and central high lands, central high lands, Deccan plateau, Telangana, and eastern ghats.
- Subhumid ecosystem includes six zones- northern plain, central highlands, eastern plateau, eastern ghat sub-humid eco region, eastern plains and the western Himalayas.
- The humid period ecosystem includes three zones- Bengal and Assam plain hot sub-humid to humid eco region, eastern Himalayas and north eastern hills.
- The coastal ecosystem includes two zones- eastern coastal plain, and western ghats and coastal plain.
- The island ecosystem includes one zone only which is Andaman, Nicobar and Lakshadweep.

The significant bit of scope of LGP based models is that the LGP is the quick quality of clamminess availability of a given landform rather than the outright precipitation. For example, both Ratnagiri in

western Maharashtra and Nagpur in eastern Maharashtra have LGP 180-210 + days, yet indisputably the yearly precipitation of Ratnagiri is more than 2000 mm. whereas that of Nagpur is only 1100 mm. Therefore, the agro-natural frameworks approach licenses crop masterminding subject to length of creating period rather than the measure of precipitation.

To Do Activity

Organize a Group Discussion for the selection of the crops according to its suitability for the agro-climatic zones on India. Discuss the factors (out of air temperature, RH, altitude and rainfall) which are most important in the zones for crop growth.

1.5 Agrometeorology and its Application

Meteorology and Agricultural Meteorology

Meteorology is derived from the Greek words comprising 'meteoro' and 'logy', implying over the world's surface (air). Meteorology is a part of science that forms study of climate. Up to 20 kms. above the lower climate the physical cycle happens. Meteorology is the blend of material science and geology, where the rule of physical science uses to examine the conduct of air (climate components like pneumatic force, temperature, dampness) and topography because of the physical exercises that happen concerning geological territories. Thus, meteorology is the investigation of climate over a specific zone, material science of air. The physical condition of the environment at a specific spot and time is called mate, while the long haul system of air factors of a given spot is called the atmosphere.

Meteorology	**Agricultural meteorology**
Study of atmospheric physics	Branch of applied meteorology deals with agriculture
Deals with weather science	Deals with meteorology and agriculture
Physical science	Biophysical sciences
For weather forecasting	For improving quality and quantity of crop production with meteorological tools
Whether dealing is a concern	Agro advisory service is a concern for the farmers based on the weather forecast
Link of science to society	Link of science to the farming community

Agrometeorology: Importance

Agricultural meteorology is a part of applied meteorology which explains the connection between climate/climatic conditions and farming creation. The relevance of Agrometeorology is due to weather and climate as both are important for agricultural production, and it's the determinant of success or failure of crop production. Weather influences the production process and its operation from sowing to harvesting.

In India there is a significant amount of damage to the crops due to climatic or weather conditions like flood, drought and storm. There is a gigantic pre-gather calamity which ranges from 10 to 100 %, while post-reap disasters run 5-15%. Along these lines, the control of agrometeorology is significant in the accompanying manners: to search for arranging of excision design/turn/choice of planting dates for ideal yield, financially savvy intercultural rehearses such as furrowing, weeding and so on, utilization of synthetic concoctions/fertilizers, judicious irrigation to crops, reduction of the spread of insects and pests, crop management, adverse seasonal management like cyclones, rainfall, flood by weather

forecasting, losses from a forest fire and mitigation strategies such as shelterbelt against cold or heat waves, etc. The need and scope of the domain agrometeorology is all-round the year. In a dry land, it helps to get the time of rainfall to decide the sowing season to get the optimum yield.

Need and scope: Agrometeorology in crop production

- Prediction of monsoon for sowing.
- Help to limit crop misfortunes because of extraordinary climate conditions, for example, flood, cold/heat waves, twisters.
- Forecasting pests attacks, selection of harvests, water system and other intercultural activities.
- Suitable yield creation rehearses dependent on neighborhood climatic conditions (Agro-climatic zones).
- Identify local gainful yield varieties.
- Crop climate announcements for ranchers, which makes ranchers more whether cognizant in arranging their horticultural activities.
- To comprehend the climatic assets of a specific zones for compelling yield arranging.
- Explore climate-based compelling homestead tasks.
- Understand the connection between climate factor rates of irritation and ailments for different harvests.
- Delineate climatic/agroecological zones for characterizing agro-climatic analogs to make successful and quick innovation move.
- Develop crop development reproduction model for evaluating possible yield in various agro-climatic zones.
- Check impact of climate on soil condition which is shaped out of climate activity.
- Reduce losses of applied chemicals and amendments.
- Managing adverse conditions of weather like cyclone, storm, floods, heavy rainfall, etc., by using the mitigation strategies like protection and avoidance.

Source: Gommes, R., H.Das, L.Mariani, A.Challinor, B.Tychon, R. Balaghi & M.A.A. Dawod. 2010.

Atmosphere: Vertical Layers of Atmosphere Based on Temperature Difference

Earth is elliptical which comprises various spheres: Hydrosphere (water region), Lithosphere (solid portion), and the atmosphere (the gaseous portion). Atmosphere is a physical mix of gases that surrounds the earth from all sides. It consists of a large number of solid and liquid particles, aerosol, which may have some permanent gases of which there are variations from time to time. There is the homogeneity of gases at lower atmosphere called Homosphere, while at the higher level of the atmosphere the chemical composition of air changes, called heterosphere. The latteer is a zone with a homogeneous composition that is up to 88 kms. in height from the earth. Heterosphere is the sphere above the thermosphere which is unequal in terms of composition. Every layer of the atmosphere differs from the other in terms of its composition.

There are several important uses such as supply of oxygen for the respiration of plants, Co2 for photosynthesis for biomass building, nitrogen for plant growth, transportation of pollen grains, protection from UV rays, maintaining the temperature of the plant and rain to the field crops. The atmosphere composition of gases is N2 (78%), O2v (20%), Ar (0.93 %), He (0.0005%), CO2 (0.03%), Ne (0.0018%), O3 (0.00004%), H2 (0.00006%) and CH4 (0.00017%).

The atmosphere is classified into layers based on temperature. They are vertically divided called spheres.

a. Troposphere– the term trop means turbulence, and sphere means layer. This layer persists of 14 kms. above MSL and 16 kms. from the equator and 7-8 kms. from poles which may fluctuate.

Most of the weather-related activities like storms, cyclones, clouds formation, etc., happen in this layer and so is called 'seat of weather phenomenon'. Maximum absorption of sunlight is thereby in the surface due to this. It is the most heated layer from below.

b. Stratosphere exists above the troposphere and goes up to 50-55 kms. above where most of the photochemical reactions happen. The temperature in it increases with the height and depends on the troposphere. The upper line of the stratosphere is called stratopause.
c. Mesosphere/ Ozonosphere is the layer where the ozone concentration of 30-60 kms. is above the surface of the earth. It is to absorb the UV rays due to which its temperature remains high, temperature increases with height with the speed of 5 degree per km. There is a middle layer of 50-80 km which is called mesosphere, where temperature declines when height increase. The mesosphere is the coldest layer in the climate with temperature up to – 95 at the mesopause (80 kms).
d. Thermosphere (Ionosphere) is the layer that lies past the limits of the Ozone layer (80-400 kms.), where the climate is half way ionized which mirrors the radio waves in light of our numerous impressions of shortwaves radio bars from ionized shells. That is why significant distance correspondence could be conceivable.
e. The exosphere is the outer layer of the earth which lies from 400-1000 kms. At such a height the density of atoms in the atmosphere is low and so the collision between the natural particles becomes extremely rare. Hydrogen and Helium gases are present in this layer.

The decline in the air temperature with increasing the height is called the typical/natural slip by rate which is 6.5°C/km.

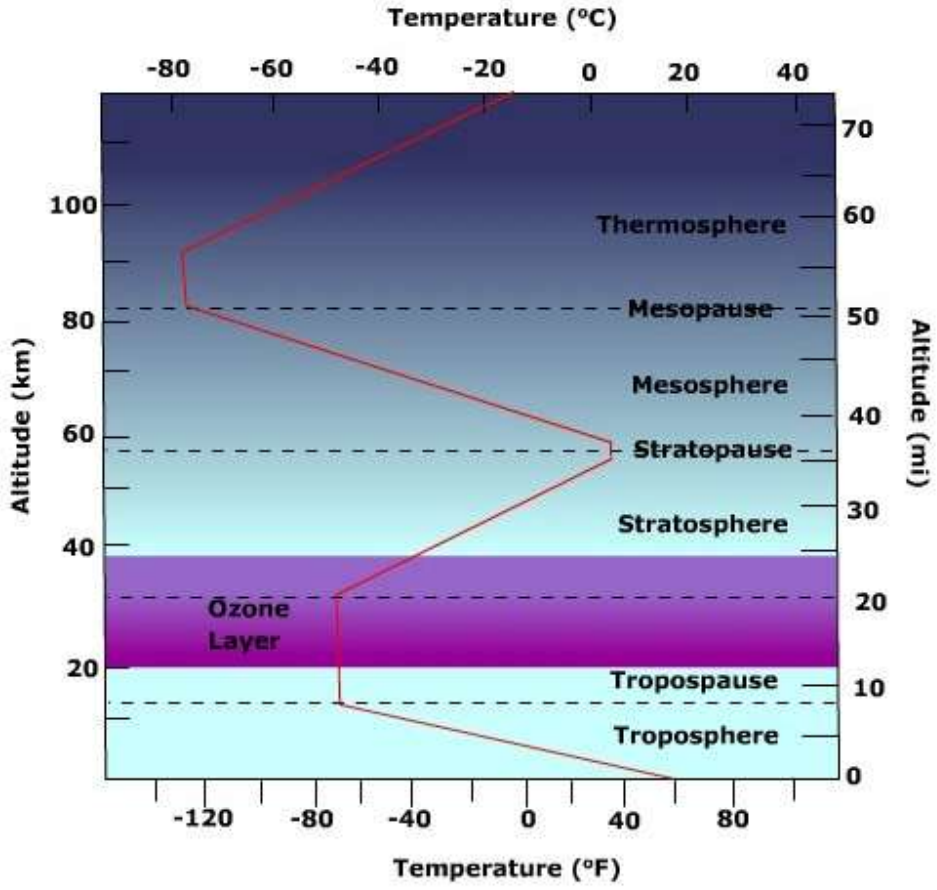


Fig. 1.8 Vertical temperature profile (International Civil Aviation Organization, 2012).

Climatology: Weather and Climate

Climatology is the investigation of the gradient of the earth. It is derived from the Greek word, Klima, which implies incline of the earth and Logos implying study. It is identified with climate changes on an everyday premise over some undefined time frame. In Climatology, climate and atmosphere terms have various undertones. Climate is the condition of air any time which shows momentary variety in the physical condition. For example, pressure, wind speed, precipitation, darkness, and so forth while atmosphere is characterized as the aggregate of the varieties in the climate states of a specific spot/district/zone during a predetermined time frame, normally a few years.

Various factors are responsible for governing the climate and weather. They are latitude, altitude (elevation), precipitation, soil type, nearness to water bodies, topography, vegetation, wind, air masses, etc. Latitude is the base to classify altitude into four categories, i.e., tropical, subtropical, temperate and polar. Altitude refers to the height from the MSL which governs the kind of vegetation, soil type and crop production of the region. The quality and amount of rainfall decide the nature of the vegetation of any area. Based on precipitation, regions are classified into arid, semiarid, subhumid and humid. The type of soil is also a product of a change in atmospheric activities.

Monsoon Rainfall Variability

The Indian sub-continent gets its annual precipitation by monsoon only which is the series of cyclones that arise from the Indian Ocean. The most important cyclones occur in June to September which cause summer storms or southwest rainstorms. There is one more second stormy season i.e., from October to December. The southwest storm is the most significant out of four periods of a rainstorms since it contributes around 80-95% of the complete precipitation. There are two sorts of storm frameworks, namely, south-west rainstorm and north-east monsoon.

a. South-west storm, in which the temperature of Indian Peninsular locale rises quickly, causes barometric weight in the inside pieces of the peninsular in the long stretch of March. In April-May the locale of high temperature moves to the north, lower Punjab and western Rajasthan. The western part of the south-west storm reaches north Karnataka, south Maharashtra and Gujarat. As the south-west rainstorm is completely executed in western India, there is another part of a similar phenomenon in the Bay of Bengal which brings downpours to Mynamar, northern segments of the east shoreline of India, Assam and so forth.

b. North-East Monsoon - In September-end the south-west tempest goes to north-western India. Yet it remains in Bengal for the entire month. There are augmentations in the barometric load in northern India. Hence, there is a move in barometric strain to south-east and north-easterly breezes begin to hit the east coast.

c. Winter precipitation is more confined to north India and is gotten as snow on slopes, with precipitation in the fields of Punjab, Rajasthan and focal India.

d. Summer precipitation is gotten from March to May as neighbourhood storms which are generally gotten in the south-east of peninsular area and Bengal. The western districts of the country do not get the precipitation.

Cloud Formation and its Importance

Clouds are the obvious total of moment water particles/beads/ice particles noticeable all around, which is ordinarily over the ground level. Mists have been characterized based on their stature and appearance, i.e., high clouds, middle clouds and low clouds. WMO (1957) has classified clouds based on their heights and appearance into 10 categories. From the height clouds are categorized into four called family A, B, C and D.

a. Family A, which is called High clouds (height 5-13km and 20000ft above MSL), includes cirrus (ci), Cirrocumulus (cc), and Cirrostratus (cs). These clouds are high. They have three sub-categories:
   - **Cirrus (Ci) -** It has ice crystals which look wispy, feathery, delicate, white fibrous and silky. Sunrays pass and it does not have precipitation.
   - **Cirrocumulus (Cc)** - It has ice crystals, looks like rippled sand and has white globular masses with no shading effect.
   - **Cirrostratus (Cs) –** It has ice crystals, looks like a whitish veil with a milky white appearance and produces 'Halo'.

b. Family B called as middle clouds (mean height 2-7 kms. and 6500-20000 ft. above MSL) includes the clouds Altostratus (As) and Altocumulus (Ac).
   - **Altocumulus (Ac)** – It has iced water and looks like sheep wool clouds.
   - **Alto-stratus (As)** – It has water and ice, produces coronas and casts a shadow.

c. Family C called as Low clouds (mean 0-2 km and close to the earth's surface 6500 ft.), It includes the clouds Nimbostratus (Ns), Stratocumulus (Sc) and Stratus (St).
   - **Stratocumulus (Sc)** is composed of water, looks soft and grey, and larger globular masses.
   - **Stratus (St)** is composed of water, mainly seen in the winter season and occasional drizzle occurs.
   - **Nimbostratus (Ns)** is composed of water or ice crystals, gives steady precipitation. It looks grey and thick, and has a uniform layer.

d. Family D- The clouds are formed due to vertical development.
   - **Cumulus (Cu)** is composed of water and white majestic appearance. It develops into cumulo-nimbus clouds with a flat base.
   - **Cumulonimbus (Cb) -** It is an upper level of the clouds having ice, while the lower level has water. These clouds produce violet thunderstorms, hails and lightning during summer.

Evaporation, Transpiration, and Evapotranspiration

Evaporation is the process from the soil. It determines the irrigation water requirement for a crop. Various factors affect it like environmental factors (such as water temperature, wind, RH and pressure); and water factors (like the composition of water and area of evaporation). Transpiration is the process where the loss of water is from existing plants. It can be stomatal, lenticular or cuticular. Many factors affect it such as plant factors and environmental factors including light, relative humidity, air temperature, wind, plant height, leaf characteristics, water availability of the plant etc.

Evapotranspiration is the process where water transpires from the plant surface and evaporates from soil surface. Multiple factors affect the ET process such as energy supply to the plant, light, temperature, relative humidity and wind velocity. The plant characteristics are like root shoot ratio, leaf characteristics, thickness of cuticle, etc. It is an important process for estimation of soil moisture to plan the irrigation schedule of the crop and to consider the association between crop yield and irrigation water.

To Do Activity

List down the factors that can be predicted or forecasted in agro meteorology. Arrange a group discussion on the application of agrometeorology.

References

- Balasubramaniyan P. and Palaniappan, SP (2002). Principles and Practices of Agronomy. Agrobios (India), Jodhpur.
- Gommes, R., H.Das, L.Mariani, A.Challinor, B.Tychon, R. Balaghi & M.A.A. Dawod. (2010). Agrometeorological forecasting. WMO Guide to agrometeorological practices, 2010 Edition, Chapter 6, WMO-No.134, Geneva. 70 pp.
- Gopalaswamy N., (1994). *Agricultural Meteorology*, Rawat publications, Jaipur, 153 p.
- Gopal Chandra De, (1997). Fundamentals of Agronomy, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- ICAR, (1996). Handbook of Agriculture, Indian Council of Agricultural Research, New Delhi.
- Mavi H.S., (1996). *Introduction to Agrometeorology*, Oxford and IBH Publishing Co., New Delhi.
- Radhakrishna Murthy, V., (2002). *Basic Principles of Agricultural Meteorology*. BS Publications Hyderabad, 261 p.
- Randhawa N.S., (1980). History of Agriculture in India, Vols. I & II Indian Council of Agricultural Research, New Delhi.
- Randhawa N.S., (1980). *A history of Agriculture in India*, Vols. I & II Indian Council of Agricultural Research, New Delhi.
- Raychaudhuri S.P., (1964). *Agriculture in ancient India*. Indian council of Agricultural Research, New Delhi
- Reddy S.R., (1999). *Principles of Agronomy*. Kalyani Publishers, New Delhi.
- Principles of Agronomy and Agricultural Meteorology, Agricultural Heritage – stages of agricultural developments – stone age-bronze age-iron age (eagri.org) retrieved from eagri.org/eagri50/AGRO101/index.html
- Sankaran S and V.T. Subbiah Mudaliar. (1997). Principles of Agronomy. Bangalore Printing and Publishing Co., Bangalore.
- Singh S.S. (1998). Principles and Practices of Agronomy. Kalyani Publishers, New Delhi.
- Yellamananda Reddy T. and Sankara Reddi (1997). Principles of Agronomy. Kalyani Publishers, New Delhi.

Model Questions

1. Differentiate between agriculture and agronomy.
2. Explain the contribution of agriculture to the national economy.
3. Dicuss the expansion of systematic agriculture in the world in general and in India in particular.
4. Explain the multidisciplinary of agronomy with various dimensions.
5. Explain the agriculture development scenario with various farming systems.
6. Explain the factors regulating the weather as well as climate.
7. What are the implications of agrometeorology on crop production?

Chapter 2 Dryland Agriculture

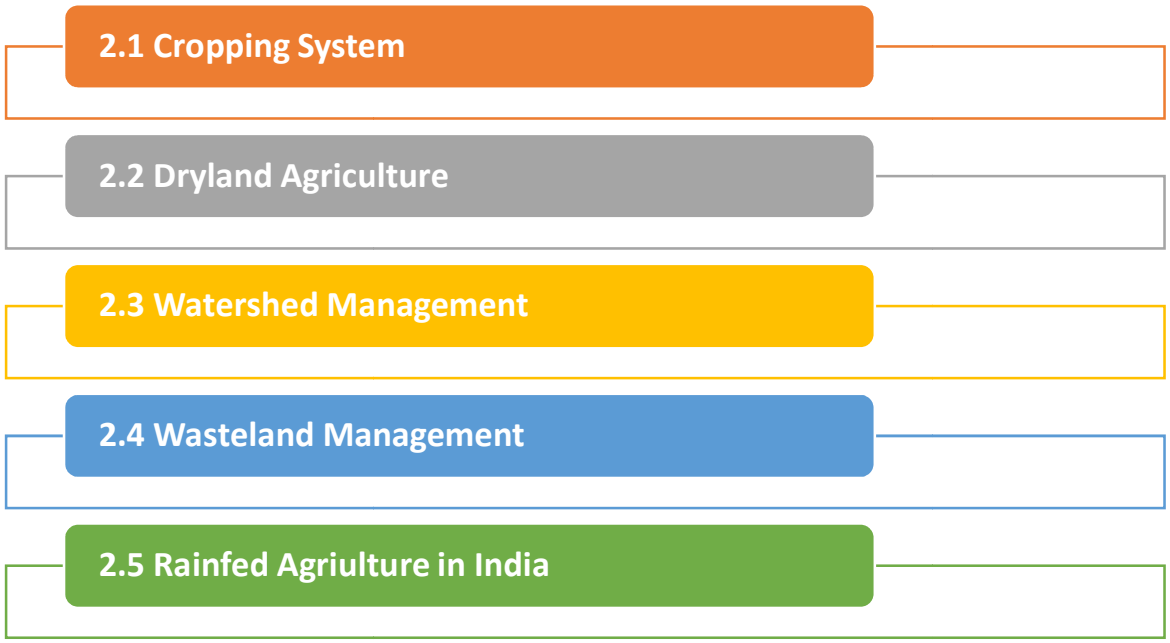
Introduction

Dryland agriculture covers a major part of the country that occupies more than 65 per cent of cultivated area. It contributes to food security as it caters to 60 per cent of livestock and 40 per cent of the human population. Dryland farming is featured with the eroded and degraded soil, low monsoon, low water holding capacity and less groundwater which results in low production and low yield that ultimately leads to land degradation. Dryland agriculture means crops are grown under rainfed conditions. There are soil moisture dynamics in dryland areas. When the rain arrives, some portion of water is received by ground through percolation process, while the portion remains on the surface as runoff. The amount of water enter the soil reaches up to the root zones, which makes surface soil dry after the rainy season. However, the surface moisture is evaporated.

Objectives

- To explain the cropping system in dryland agriculture.
- To analyse the various dimensions of dryland agriculture.
- To look into watershed management and programme on the watershed.
- To explain the wasteland, definitions and reclamation strategies.
- To understand the scenario of rainfed agriculture in India.

Chapter Structure



2.1. Cropping System

The cropping system consists of various components which have relevance to agriculture whether for self-sufficiency or commercialization. Unlike commercial agriculture, individual farmers follow the cropping system based on the adaptability of the crops according to the climate and season, domestic need and profitability. The cropping system is the main component of the farming system which needs to be decided by the production technology as well as management practices. It is about the editing design which is embraced in the homestead and its communications with the ranch assets, other ranch ventures and accessible innovation. It prompts proficient utilization of accessible assets and directs a decrease in the cost of production. It is the extent of the region where yields are developed for a specific purpose of time in per unit region. It may be yearly sequencing of yields or spatial game plan of the harvests in a specific territory. Crop rotation intends to become an arrangement of harvests on a similar piece of land either yearly or over a more drawn out timeframe without weakening the soil fertility to increase the benefit with a low investment that may have a full development of the arranged progression of yields.

Box 2.1 Principles of Crop Rotation

Principles of Crop Rotation

- Taproot crops should be followed by adventitious roots for a proper use of nutrients and water from the soil.
- More thorough yields are followed by less comprehensive harvests (potato, sugarcane and maize need a larger number of contributions than oilseeds and heartbeats).
- Leguminous crops need to be grown after non-leguminous crops for nitrogen fixation.
- Crops selection should be based on land altitude, land slope and soil type.
- Crop selection should be created on demand of the place to fetch good marketability and price.
- The same family crop should not be in succession as it can attract the same pest and disease pathogens.

Source : Chandrasekaran B, Annadurai K and Somasundaram E, (2010)

Crop rotation is advantageous as it maintains soil fertility, timely agricultural operations, insect pest control, proper utilization of resources and increased crop productivity. Effective cropping zones are the idea of editing design where the extent of the zone with different arrangements of harvests at a specific time in the given zone.

Efficient Cropping Zones

The cropping pattern characterizes the extent of land distributed for different harvests at a specific timeframe in a given region. Cropping pattern can be characterized empirically, that is, annual grouping and altitudinal sequences of action of harvests in the given territory. Effective cropping zone implies the territory where efficiency of harvests goes on higher because of ideal conditions for crop development and profitability. There are various cropping zones like rice zone, wheat zone, sorghum zone, maize zone, bajra zone, finger millet zone, pulses zone and forage crops zone.

Table 2.1 Efficient cropping zones in India

Efficient Cropping Zones	Particulars
Rice zone	In India about 49 per cent area of the rice zone is rainfed while 51per cent area is irrigated. Punjab, Tamilnadu, Andhra Pradesh are the states, which is the potential for rice crop production. The northeast part of the country, Odisha, West Bengal, Bihar has the potential for rice cultivation.
Wheat zone	In India the zones are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh whichhave the highest wheat productivity. About 85 per cent of the total wheat zone is under irrigation, while the rest of 15 per cent is rainfed.
Sorghum Zone	Sorghum grows mainly (94 per cent) in rainfed areas like Maharashtra, Madhya Pradesh, Andhra Pradesh and Tamil Nadu. Some sorghum zones under black soil have been diverted to other commercial crops like sunflower in the southern zone and maize in the western zone.
Maize Zone	Most of the maize zone such as Uttar Pradesh, Rajasthan, Bihar and Madhya Pradesh is rainfed. Maize is grown in irrigated areas between December and July-August, while as a rainfed crop in the months of September-October.
Bajra Zone	Bajra zone is mainly rainfed condition. It has low rainfall in north-western part of India like Rajasthan, Maharashtra, Gujarat and some parts of Uttar Pradesh.
Finger millets Zone	Finger millet is one of the major cereal crops of Karnataka.
Pulse Zone	India is one of the largest producers and consumers of pulses in the world. The pulse zone is Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh.
Chickpea Zone	Primary chickpea producing zones are Madhya Pradesh, Rajasthan and Uttar Pradesh.
Green Gram Zone	Green gram zones are Maharashtra, Andhra Pradesh and Tamil Nadu.
Forage Zone	Good forage crop zones are Punjab, Uttar Pradesh, Haryana, Bihar and Gujarat.

Cropping System

The cropping system across the country varies. Sometimes there are two crops in a year in sequence and at other times intercropping of various crops. Multiple cropping land is divided into lowlands and irrigated upland, and rainfed uplands.

- The swamp watered upland rice-based system frameworks are predominantly in swamps. In the time of precipitation over 200 mm. for each month, up to nine to ten months, the cropping system is of rice.
- In irrigated upland areas where the winter is mild, upland crops can be taken up which include rice and some legume crops (such as soybean, black gram, cereal crops like maize, pearl millet) and other crops (like sunflower and vegetables). In northern India maize, wheat, etc., are

cultivated either by relay cropping or delay wheat for about two months and after harvest of wheat, short-duration green gram or fodder crops can be grown in summer.

- In the case of rainfed uplands, the major cropping systems in the type of intercropping in Alfisols, Inceptisols, and Entisols in the stormy season. In the non-rainfed cropping system, agronomy managed all the practices constrained by the ranchers which contribute to the profitability of yields. Intercropping system is the common practice of rainfed agriculture.

In intercropping two or more dissimilar crops grow on the same piece of land, the purpose being to increase crop productivity per unit area by increasing the pressure of plant population wherein legume and non-legume crops are taken up. There are advantages and difficulties/ challenges of intercropping.

Table 2.2 Advantages and Challenges in Intercropping Cropping system

Advantages	Challenges
• Additional income from the companion crop.	• Fertilizer management due to legume and non-legume crops.
• Sustenance income from the companion crop.	• Harvesting time and techniques for crops are different.
• Nitrogen fixation due to legume crop as well as utilization of soil moisture,	• Suppressive crops may affect the companion crops.
• Better utilization of growth resources, nutrients, water, light and space.	• Companion crop may invite insect pest.

Cropping System and its Types

The cropping system refers crops, their sequencing and management practices done on a particular piece of land over time. There are various types of cropping systems as shown below. They are as follows:

- **Sequential cropping** is also called double cropping. This is the preparation of growing another crop proximately after the harvesting of the first crop. So two crops can be harvested in the same year on the same piece of land.
- **Intercropping** is the production of two or more crops in the same piece of land in the same time. The two crops compete with each other in the field. Both the crops are main crops as well as intercrops in rows and this is called row intercropping where weeding harvesting and other intercultural operations are comparatively easier than mixed cropping.
- **Monocropping** is also called monoculture where a single crop is grown in the field. The same crop is cultivated year after year in the same field and it can be called as continuous monocropping. For example, planting wheat year after year on the same piece of land. Its disadvantage is that the land becomes infertile by losing its fertility slowly which may cause attacks by insects, pests and diseases.
- **Relay cropping** is where various crops are planted at various occasions in the same field. Hand-off cropping system is one of the strategies of growing another crop before the harvest of the existing crop. This assists in forestalling rivalry between the principle crop and the intercrop where the field can be utilized for the more extended term.
- **Strip cropping** is where at least two yields are in the same field planted in strips and so the plants competition is inside the harvests rather between the yields.
- **Crop rotation** is changing crops in the field each season every year.

- **Mixed intercropping** is distribution of seeds of two crops without any arrangement. It seems an easy process but it is difficult for particular operations because there is a possibility of crops competing with each other.
- **In stir cropping** there are broad rows of strips of several crops in the same field and the sizes of the strips are almost 3-9m. On the slope of land strip crops can be grown and this prevents soil erosion. Its other advantages are that it produces a variety of crops and the residue of some crops can be used for the soil conservation mechanism for another crop.

Components of Cropping System

Table 2.3 Components of cropping system

Tillage system and residue management	Cropping system	Nutrient and water management	Erosion control practices
• No tillage • Chisel tillage • Mulch tillage • Stripe tillage • Residue removal • Residue burning • Partial residue removal • Quality of residues	• Fallows system • Monoculture • Strip monocropping • Multiple cropping' • Contour strip cropping • Crop rotation • Cover crops • Mixed and relay cropping • Organic farming	• Precision farming • Use of amendments (manures, compost, etc.) • Enhancement of biological nitrogen fixation (BNF) • Irrigation/ drainage practices • Water harvesting	• Conservation buffers • Windbreaks and buffer strips • Terrace and engineering devices • Sedimentations basins

Source: Blanco and Lal, 2010

Cropping pattern and arrangement of crops framework in India has the decision of crop development of farmers which is guided by different components like physical, social and climatic condition. Cropping pattern is unique and changes over the timeframe and space. It can be said that the changing cropping pattern is the annual planning and spatial strategic plan of sowing a giving fallow land of a given area. In India there are various factors which determine the cropping pattern like rainfall, climate temperature, soil type and the intervention of technology.

To Do Activity

1. List down efficient cropping zones of fine cereal crops, coarse cereal crops and pulse crops across the country.
2. Discuss different cropping systems and their components in various states of India.

2.2 Dryland Agriculture

Dryland agriculture is a kind of agriculture where the crops can be grown completely under rainfed condition. Places and the amount of rainfall govern the agricultural pattern in it. On the basis of the quantity of rainfall, dryland agriculture has been classified into various categories.

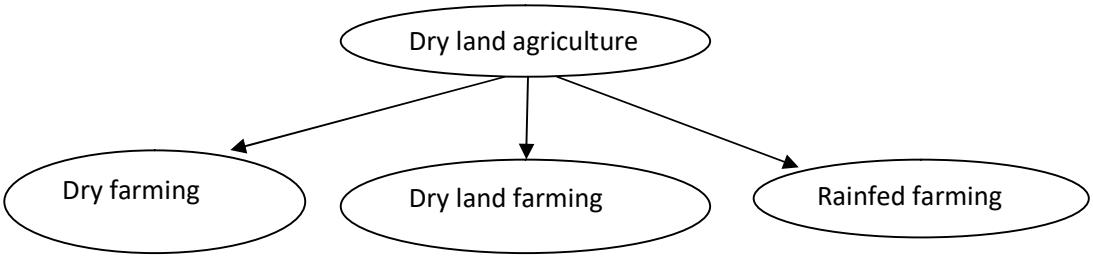


Fig. 2.1 Categories of Dryland farming

They are dry farming, dryland farming and rainfed farming.

- Dry farming is the farming practice where crops are cultivated where the annual rainfall is less than 750 mm. These are called arid region where for most of the crops wilting chances are high due to dry spell. Preservation practices are essential for crop production. Soil and water conservation, sustainable cropping pattern and limited use of fertilizers are the features.
- Dryland farming is done where annual rainfall is more than 750 mm. In this region the graph below chances are comparatively less but still it is a semi-arid region. Production and growing periods are not more than 120 days. Crop and soil moisture conservation practices are necessary.
- Rainfed farming is in areas where the yearly precipitation is more than 150 mm. The produces is not exposed to the pressure of soil dampness. However, it isa humid area where the crop period is 120 days or more.

According to UNESCO, Asia and Pacific region use different connotations as the terms in arid and semi-arid regions. Similarly, in some places the terms tropical and temperate have been used but with some differences. The arid and semi-arid region, is related to moisture, while the tropic or temperate region to the thermal or temperature regime of the area.

- Arid region of the world has low precipitation which is under 200 mm. a year. There are five desert zones over the world:
    - North African Eurasian Sahara and Thar Desert,
    - North American desert Arizona in USA,
    - South American desert in Peru,
    - South African desert of Namibia, and
    - Australian desert in Central Australia.

There are two characterizations of the semi-arid area. There are semi-desert jungles and semi-desert cold districts which spread over more than 48 nations in Asia, Australia, America and Africa. Precipitation ranges from 400 to 750 mm. each year. If an occurrence takes place in semi-desert cold area, it covers Russia, China, USA and Canada where temperature remains less than 18 degree Celsius, while the maximum temperature reaches up to 33 degree Celsius.

Indian Agricultural Scenario

Indian agriculture is a combination of various factors that influence the location of any place, temperature, rainfall precipitation, rate humidity and other climatic factors.

- Location of India
- Temperature
- Rainfall
- Monsoon

India is a tropical country that is located between 8 degree and 36 degree north of the equator and 68- and 96-degree east longitude. There is temperature variation between the northern and southern parts of the country. It experiences uncertain rainfall in successive years. There are some deserts located in Western Rajasthan where rainfall is less than 100 mm, while in Eastern India the annual rainfall may be more than 10000 mm. In some parts of the country the rainfall may be for one or two months and in other parts may be for more than 10 months in a year. There are aberrations in rainfall. When there is a deficit in the rainfall, it adversely affects crops but if there is more rainfall than the storage capacity of soil is less. Erratic distribution of rainfall leads to runoff, long dry spells during the crop growth and cause moisture stress. Sometimes early withdrawal or deficiency of rainfall may cause stress of maturity or reduce the crop yield. Rainfall is a primary source of water for plants. Occurrences of droughts are the consequences of erratic precipitation over a continuous period of time.

India has two types of monsoons. Almost 80 per cent of the total annual rainfall is received in the monsoon season. The main rainy season is from June to September that is called south-west monsoon which is in the south of India and moves towards the west of the country. The distribution of rainfall extends to about two to four months in the most agricultural region in northern and north-western India while it extends to five months in Peninsular India. It has a much longer duration in the southern areas like Bangalore and Trivandrum.

The study of rainfall over a long period of time is known as rainfall climatology. It reflects the general pattern of rainfall in a particular place. The analysis of rainfall is helpful to understand the pattern of irrigation and scheduling of irrigation. To understand the pattern of rainfall is essential in order to design farm ponds and tanks for irrigation projects. There are different types of precipitation and buildup type of mist. Dew and frost are not considered precipitation. Excess rainfall causes a reduction of yield. It may lead to the runoff, plant nutrients are leached down to the root zone and crops adversely affected by anaerobic condition.

Rainfall Analysis

Rainfall analysis includes intensity of rainfall, its distribution, dependability and reliability.

- Intensity of rainfall influences soil erosion which helps understand the probable period of flood filling of irrigation tanks, etc. If the intensity of rainfall is high exceeding more than the soil infiltration rate, then runoff occurs which may lead to soil erosion.

Table 2.4 Rainfall Intensity and runoff

Rainfall intensity	Runoff
Less than 12.5 mm.	Runoff is rare.
12.5–25.0 mm.	Runoff on 35.per cent occasions
25.0–50.0 mm.	Runoff on 80 per cent occasions
Above 50.0 mm.	Runoff on 100 per cent occasions

- The circulation of precipitation is the measure of precipitation got at the intermittent stretches' weeks, months, seasons and so forth. Circulation of precipitation is a priority than the absolute precipitation.

- Dependability of precipitation in dry cultivating is a significant element and habitually happens in the amount of precipitation beginning and closing of stormy season span of precipitation and circulation of precipitation inside stormy season. Dependability of precipitation can be assessed by 75 per cent likelihood of precipitation and by coefficient of variety.

- By ascertaining coefficient of variety, the variety in precipitation can be measured. If the coefficient of variety is high, it implies that the variety in a precipitation from year to year or season to season is high while if less, it implies that it is extremely less and more reliable.

Coefficient of variation= Standard deviation/Mean X 100

Scenario of Dry Farming in India

Since, 1950 the degree of irrigated land in India or over the world has been expanded from 94 million hectare to 20 million hectares. In India very nearly 43 million-hectare land is a developed region out of 143 million hectares which is irrigated, while the rest of the land is rainfed. Maize and chickpea upto 85 per cent are in rainfed zone. The yearly normal precipitation is just about 1200 mm., which is marginally over the global mean of 990 mm. Just 20 per cent of the zone in India is secured with precipitation between 1 to 500 and 2000 mm. And 10 per cent zone with yearly precipitation is in excess of 2000 mm. In dry land farming there is scope for agroforestry, social forestry, silvi pasture, etc., which do not supply food but fuel to the village people as well as to the cattle but forms a suitable vegetative cover for ecological maintenance.

Factors Affecting Dry Farming

Most of the cropping in the area comes under semi-arid zones that is continuously rainfed. Factors affecting dry farming help poor resources which was only low input subsistence farming, and which makes do an unstable farming yield. There are multiple factors which are a constraint for dry farming like:

- In climatic constraints there are factors like atmospheric temperature, relative humidity, high atmospheric water demand (i.e., potential evapotranspiration), precipitation in most of the time of the year and vagaries of monsoon.

    - Variable precipitation additionally impacts the coefficient of variety. Questionable downpour or most successive downpours require an explanation while less precipitation another explanation.

- Power and conveyance of precipitation impacts the harvest efficiency. By and large, over half of the absolute precipitation for the most part gets within a week or three to five stormy days which means a significant loss of water because of surface water spillover which leads to soil erosion and consequently the total rainfall affects the dryland agriculture.
- Late onset of monsoon is another reason where the crop varieties which is recommended for the region that is not allowed to show in that time. Delayed sowing may cause uneconomical crop productivity.
- Early withdrawal of monsoon is equally dangerous meaning terminal stress on crops, leading to poor productivity.
- When there is a break in the monsoon for more than 15 days, there is a critical condition for soil moisture affecting productivity.

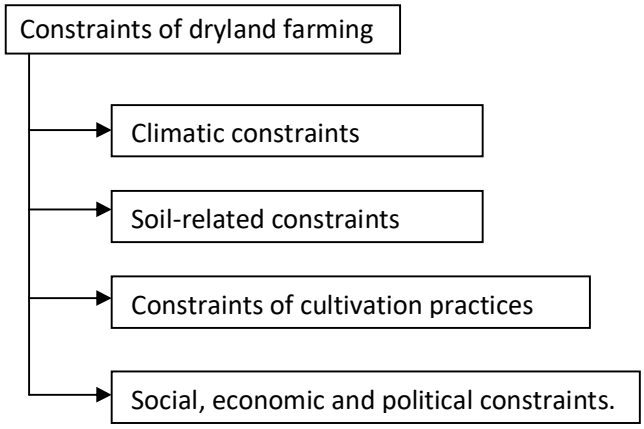


Fig. 2.2 Constraints of dry land farming

- Soil constraints are inadequate soil moisture availability, poor soil fertility, soil deterioration (due to erosion like wind, water, etc.) and others.
- Cultivation practices need to be adopted based on the long experience of farmers. There are traditional practices which cause low and poor quality yield.

    - Some traditional practices like ploughing with a country plough can be replaced by a tractor.
    - Broadcasting seeds behind the country plough leads to poor yield and uneven plant growth.
    - Selection of poor quality of traditional varieties of seeds.
    - Hand weeding, mixed cropping, conventional system of harvesting, traditional storage system, etc.
    - There are certain practices which need be followed like monsoon sowing of certain crops (maize, red gram, bajra, etc.), choice of crops on the basis of rainfall, etc.
    - Most traditional practices are not aimed at good farm management practices such as moisture conservation, nutrient status and fertility status of soil, calculation of plants per unit area, etc., which reduce the yield.
- Socio-economic constraints of the farmers impact production and productivity of crops. Cultivation practices vary in states. In Punjab, Haryana and Tamil Nadu they are as per the arid or semi-arid

regions. The intercultural operations as well as cost of production in the regions depend on the socio-economic conditions of the farmers.

Soil Fertility Management under Dry Farming

There is lot of indecision of return from the speculation of fertilizer use and poor resources in case of dryland farming the fertilizers used in the trial and farming crisis between 5 to 50 kilo per hectare nitrogen, Phosphorus and potash. Many practices need to bee followed in the dryland area for increasing water absorption to prevent the erosion at the surface area. There is need to check the measures to reduce the runoff water to prevent water logging. It can be done through measures like,

- Cropland should be as level as possible to mitigate slope in the field.
- Tillage and planting must run across the slope of the land to make a ridge for downward flow of water. There should be reduction in the loss of soil moisture and soil evapotranspiration is needed.
- Bunding is necessary and at every fall of two feet, bund of 18-24 inches in height be constructed. It will help to retain water and minimise the loss of topsoil.

All the growing plant extract water from the soil and evaporation is somewhere only in steps. This process is called transpiration. If there can be a mechanism to minimise the effect of drought stress in such carrier crop varieties, which is identified for dryland farming, where the smaller number of leaves with little leaf surface, fewer stomata and remaining closed during the stresses. Some plants become resistant to drought stress by secretion of waxy coating on their leaves.

Dry farming practices are a complete package of techniques which can be helpful for a coming draught to reduce the stress which occurs due to dry climate. Mulching can be one of the practices which help to reduce the rate of transpiration.

To Do Activity

1. List down the activities suitable for the dryland agriculture in the drought-prone states in India.
2. Discuss the measures to address the dryland constraints including climate, soil, cultural and socio-economic constraints.

2.3 Watershed Management

In our country most of the poor and marginal farmers rely on the degraded land and water resources for them are poor. They are struggling to get acquainted with the climatic situation, production and market risk. The rate of deterioration of crops is very high in the case of rainfed area, where more chances of soil erosion and runoff is there. In the critical area, where there is more adversity for ecosystem services, there how to produce good production of crops is challenging. Watershed is a confined geographical unit with the common drainage. By a system of drain which is the land and water area that which contributes run off to a common point. Water characteristics like inflow, water use, outflow, storage, these are the predominant factors should be considered for sustainable water management.

- In case of inflow water, the forms are precipitation, surface water inflow, ground water inflow.

- While the use of water is in the form of evaporation, evapotranspiration, irrigation and drinking water.
- Outflow water is surface water outflow, groundwater outflow.
- While the storage of water is in the form of surface storage, ground water storage and root zone storage.

The significant mediations if there should be an occurrence of water the executives are water reaping, groundwater revive, support of water balance for forestalling water contamination and monetary utilization of water. Out of all these, water collecting is a significant segment of the water reaping. In water the board there are sure savvy water reaping structures like permeation pits or tank revive channels, energize wells, ferro concrete tanks, ranch lakes, V discard and seat terracing.

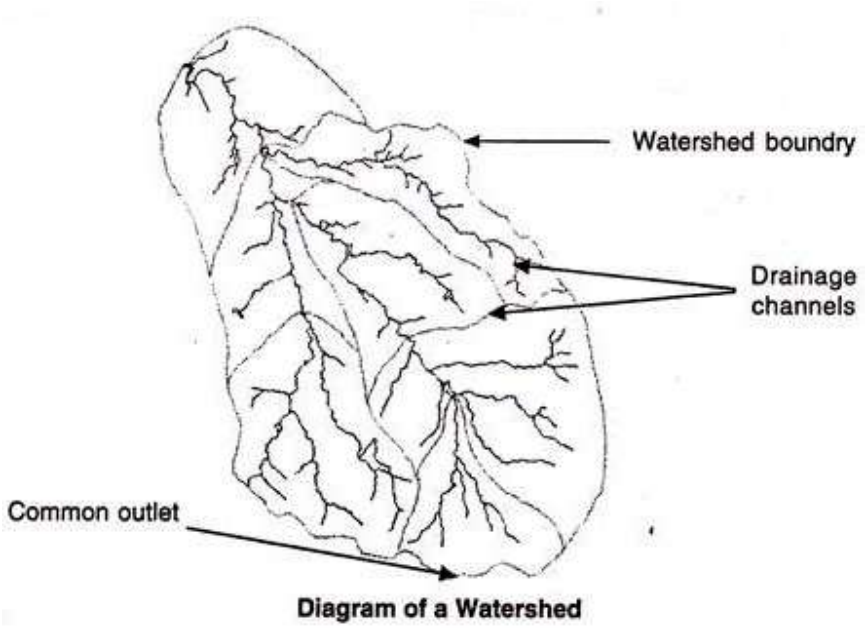


Fig. 2.3 Watershed

Watershed management involves judicious use of natural resources where there is active participation of Institutions, organisations, community mobilization; all are used in equal harmony with the ecosystem. All the resources like land water, Vegetation of the area are responsible to reduce the fear of moderate plants prevent, soil forestall, soil disintegration, improve water accessibility at increment food, fiber and fuel on that territory on the reasonable way. This is to accomplish most extreme degree of creation with least dangers of the common assets and for government assistance of the general public. Watershed Management is an exhaustive and incorporated multi asset the executives arranging cycle to discover the offset with environment, monetary and social just as socially inside a watershed. Watershed the executives is coordinated anticipating area and water which comprises of both ground and surface water stream, which consider getting ready for the connection of water plants creature and human land, can found inside the physical limits of a watershed.

The watershed has been presented in 1920, which was utilized for water separating limit. It implies the zone of land which is having a channel or which contributes escape with a typical outlet. Watershed characterize as a geo hydrological unit with the normal seepage. Watershed the executives is the

procedure utilized in rainfed territories, which infers a viable preservation of soil and water assets for economical creation with less toxin misfortunes. It includes the board of land surface and vegetative measures to moderate the dirt and water for the advantages of farmers.

Watershed Management: Types

There are various types of watershed. It has been classified on the basis of size, drainage, shape, land use pattern and geographical area. The types are, macro watershed, sub watershed, milli watershed, micro watershed and mini watershed.

There goals of watershed are creation of food, grain and fuel, contamination control, over misuse of assets ought to be limited, water stockpiling, flood control, checking sedimentation, Untamed life safeguarding, control and anticipation of soil debasement and protection of soil and water. Business age for mechanical turn of events and recharge of groundwater to provide regular water supply as well as recreational facilities.

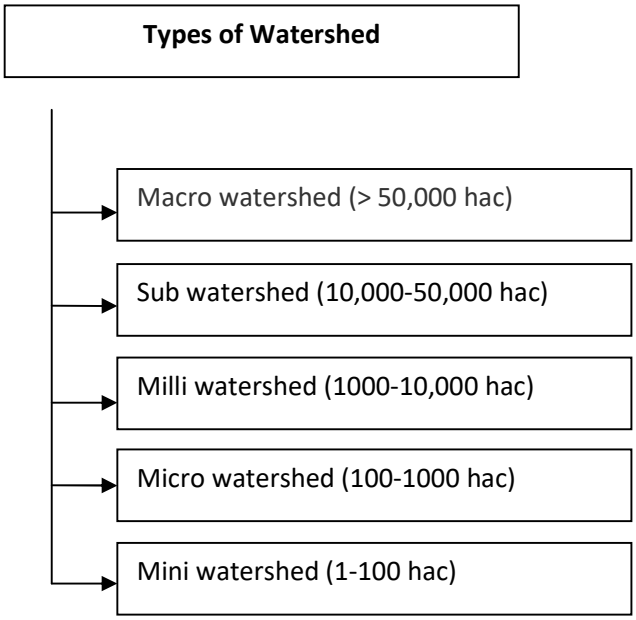


Fig. 2.4 Types of watershed

Benefits of Healthy Watershed

There are different benefits of healthy watershed, these are in terms of the human ecology and economic aspects, in which any watershed management is to make a balance as well managed resources. There is abundant supply of clean water that is necessary for the economy. Water supply should be for the municipality, business, agriculture producers' industries, as well as for the life and social aspects.

Components of Watershed Management

Various mechanisms of watershed management include soil and water conservation, water harvesting, water management and alternate land use system. Irrigation projects with the watershed management that can be categorised as major medium and minor irrigation projects. The major irrigation project means which cover more than 10000 hectare of catchment commanded area. the medium projects from 2000 to 10000 hectare of estimate command area while the minor is the less than 2000 hac of catchment area.

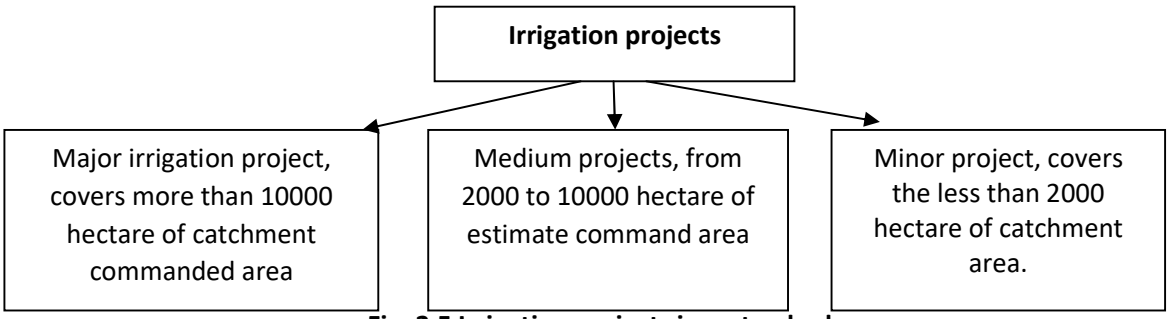


Fig. 2.5 Irrigation projects in watershed

Three major component of watershed Management are land management, water management and biomass management.

1. The Land the executives incorporate different highlights of land like moderate development profundity surface dampness in readiness rate and soil properties. There is different land the board mediations Such as auxiliary measures, vegetative measures, production measures, and protection measures.

    - The auxiliary measures incorporate different basic intercessions like shape bunds, stone bunds, reviewed bunds, form channels, terracing, channel dividers, field bunds and so forth.
    - Vegetative measures for the watershed the board incorporates vegetative force plant spread mulching vegetative supports, field the executives Agroforestry and so on.
    - Production measures remembers different intercessions for request to build the efficiency of land with the measures like covering crop rotation, land levelling, use of improved variety of seeds conservation, tillage, strip cropping, mixed cropping, cultivation of shrubs and herbs.
    - Protection measure is another measure of watershed Management which includes various measures like gully plugging, land slide control and runoff collection etc.

2. Water resource management plan is a kind of resource management plan that try to make a sustainable development of watershed which involves number of techniques. The efficient way of surface water storage, soil moisture conservation of groundwater recharge technologies used to the adopted under water management development plan. There are various methods of cultivation across the slope irrigation, water management through drip and sprinkler method as well as plantation of horticultural crops on the contour bund.

Fig 2.6 Water resource management

3. **Biomass management**

- Biomass Management is an important area which indicates with major interventions. The major intervention areas are eco preservation, biomass regeneration, forest management and conservation increased productivity of animals and plant protection in social forestry.
- Sediments is one of the reasons to divide the water quality river and lakes it effects on the wetlands and block the penetration of light into water bodies which kills the aquatic flora and fauna.
- Rainwater harvesting is another method for rejuvenating of traditional water tank. Rainwater harvesting is the accumulation as well as the position of rainwater which can be used later for the drinking purpose and for livestock animals, which can be used for irrigation of plants.
- Artificial energize is expected to upgrade the ground water accessibility which will be a positive methodology for gracefully round the year.

In Maharashtra, there are many water harvesting projects that has been adopted in different villages and explained it as a employed strategy to overcome the encounters of the water crisis. In most of the places with enthusiasm the community has been mobilized and they have been we cover the major challenges the people of Bhadli, Jalke, Katpur, Ringangaon, Ralegaon Siddhi and many more in Maharashtra. They are enjoying the best project as a gift of nature for with the help of water harvesting.

Fig. 2.7 Watershed management programme[1]

The people of Bhadli, Jalke, Ringangaon,katpur in Maharashtra are now enjoying the gift of nature as a blessings of these projects

Watershed Management Programmeme: Steps

In watershed the executives programmes which includes in the assurance of elective land treatment measures and that incorporates about the issue of land soil water, and vegetation related data about

[1] **Source:** https://www.ssiast.com/activities/watershed-management.aspx

the watershed. Any watershed has been partitioned into Various stages. The watershed programme stages are recognition stage, restoration stage, assurance stage and improvement stage.

(i) Recognition stage has again partitioned into different advances like acknowledgment of the issue, after the acknowledgment of issue there is the investigation of reason for the issue and its impact and based on the circumstances and logical results. There was an improvement of elective arrangements off issue.

(ii) In the Restoration stage, it remembers for 2 stages, these are the choice of a best arrangement of the issue, which are recognized and use of the answers for the issue in that specific region.

In instance of assurance stage, to deal with general strength of the watershed and about guaranteeing to their typical capacity. In the fourth phase of watershed Management programmeme, improvement phase is the phase where generally improvement in the watershed and land is secured, which incorporates horticulture and Forest administration and its creation. Woodland creation and the board, social monetary conditions so as to accomplish the watershed management goals.

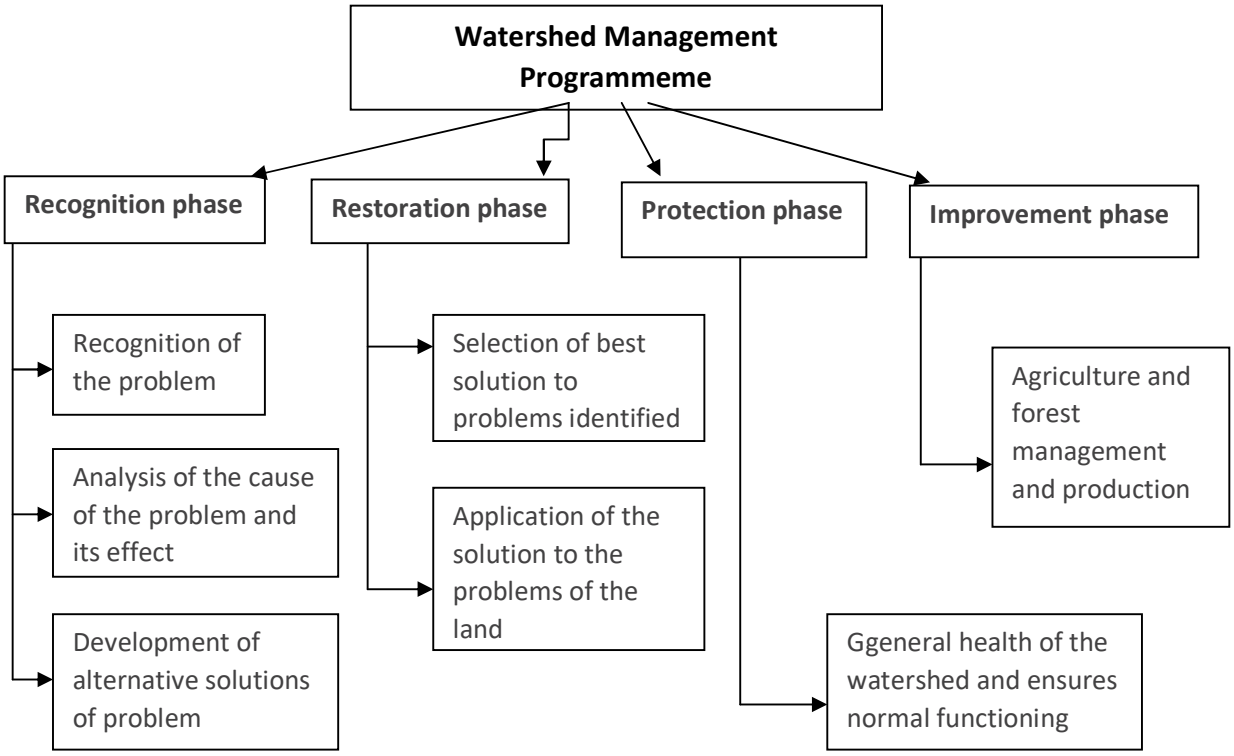


Fig 2.8 Steps in Watershed Management Programme

(iii) Protection Phase:

This stage deals with the overall soundness of the watershed and guarantees typical working. The security is against all elements which may cause decided in watershed condition.

(iv) Improvement Phase:

This stage manages generally speaking improvement in the watershed and all land is secured. Consideration is paid to farming and timberland the executives and creation, search creation and field the board, financial conditions to accomplish the destinations of watershed the executives.

Watershed Management Programmemes

Watershed management programmeme has been initiated by the Government of India. The programmes are Drought-Prone Area Programmeme (DPAP), Desert Development Programmeme (DDP), National Watershed Development Programmeme (NWDP) for rainfed agriculture, Control of Shifting Cultivation (CSC), World Bank-Assisted Integrated Watershed Development Project (WBIWDP).

- DPAP was initiated in 1970-71 with the objective of restoration of logical balance and optimum utilisation of natural as well as human resources for mitigation of effects of drought.
- DDP was initiated in 1977- 78 to mitigate the effects of droughts in desert areas and restore ecological balance.
- NWDP for rainfed agriculture was started in 1986- 87 with the objective of conservation and utilisation of rainwater from arable as well as non-arable land on watershed basis.
- CSC was initiated in 1986- 87 for respiration of ecological balance, specially in the hilly areas to improvise the socio-economic conditions.
- WBIWDP was initiated in 1990 for understanding and reducing environmental degradation and promoting sustainable increase in agricultural production.

Water Management Practices

There are water management practices like vegetative measures, agronomical measures and engineering measures for structural practices. Vegetative or agronomic measures are:

(iii) Strip cropping,
(iv) pasture cropping,
(v) grassland farming, and
(vi) woodland.

Engineering measures or structure and practices include:

- Terracing,
- contour bunding,
- construction of earthen bank,
- construction of check dams,
- construction of ranch lake,
- construction of redirection,
- structure foundation of perpetual field vegetation,
- providing vegetative and stone obstructions, and
- rock dam.

Therefore, watershed management plans to protect watershed or prevent damage to mitigate the effect of land use to an acceptance level. It is a multidisciplinary approach and objective of planning is not only about prevention of watershed dictation but also about increment of production from the farm land on a sustainable manner as well as long-term improvement in the lifestyle of the community. Watershed management can be defined as an analysis, fortification, reparation and conservation of a drainage basin for the optimal control and maintenance of water with optimum utilisation of resources.

To Do Activity

1. Define a watershed and find the areas where watershed management can be implemented.
2. List watershed management measures with cultural, technical, community-based and agronomic practices.

2.4 Wasteland Management

'Wasteland' has multiple connotations. Soil Science Society of America 1956 defined it as land which is not capable of producing materials or service of value for miscellaneous land type. According to the Ford Foundation, it is land producing less than 20 per cent of its potential. There is various definitions of wasteland which include degraded forest which is over-grazed, revenue wasteland, hilly slope, eroded value or drought-prone area, over-irrigated area, usar or khar land, marshy land, etc. The National Wasteland Development Board in 1987 defined wasteland as corrupted land under vegetative spread with occasional endeavours and which is disintegrating for lab of suitable water and soil the board or by virtue of common causes. According to th Society for Promotion of Waste Land Development, it is land which isn't creating green biomass conflicting with the status of soil and water, and it must be treated as no man's land. The Society suggested that wasteland can be classified on the basis of ownership like forest land which can include degraded forest/farmland. Since there is no commoly accepted definition of wasteland, it is land which does not give an economic return. Wasteland can be considered as unfit for cultivation having water logging or other issues related to the fertility of land.

Occurrence of Wasteland

According to the National Commission on Agriculture, around 175 million hectares of land is degraded in India. It may include about 85 million hectare of agricultural land, 40 million hectare of degraded forest land and about 50 million hectare of community and other categories of land. The National Watershed Development Board (NWDB) has given other categories of land. It has added around 36 million hectare land as degraded forest land and estimated total of 129 million hectare of land.

Classification of Wasteland

Wasteland can be classified into two categories: first, is barren and uncultivable wasteland, and second, cultivable wasteland.

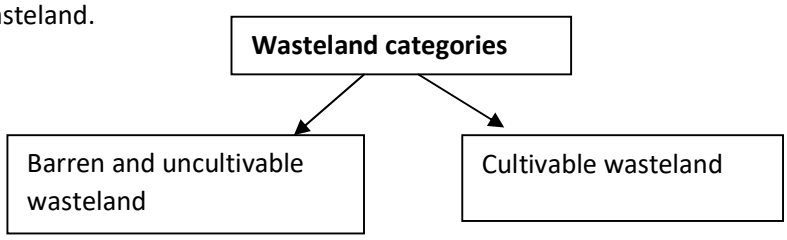


Fig. 2.9 Wasteland classification

- Barren and uncultivable wasteland cannot be brought under cultivation or it doesn't have any economic use. It may include sandy desert gully lands, stoney leased land on hill slopes and rocky exposures.
- Cultivable land is not cultivated for five or more years. It is not cultivated but cultivable like the land which is kept as fallow land adjacent to cultivable land. Most of the wastelands lies in Rajasthan anthropogenic activities such as waste land formation are deforestation overgrazing and intensive agricultural practices.

Reclamation of Wastelands

There are various methods for the reclamation of wastelands. They can be used for the excess water, afforestation or agronomic purposes conserving the soil. Contour bunds can be constructed which will be affordable for disposal of water in the catchment area. It can be used for settling landless agricultural labourers.

Appropriate planning is required for the development of the wasteland which can be used by various technologies such as remote sensing and geographic information system. It needs to be mapped out on a sufficiently large scale and a detailed action plan generated.

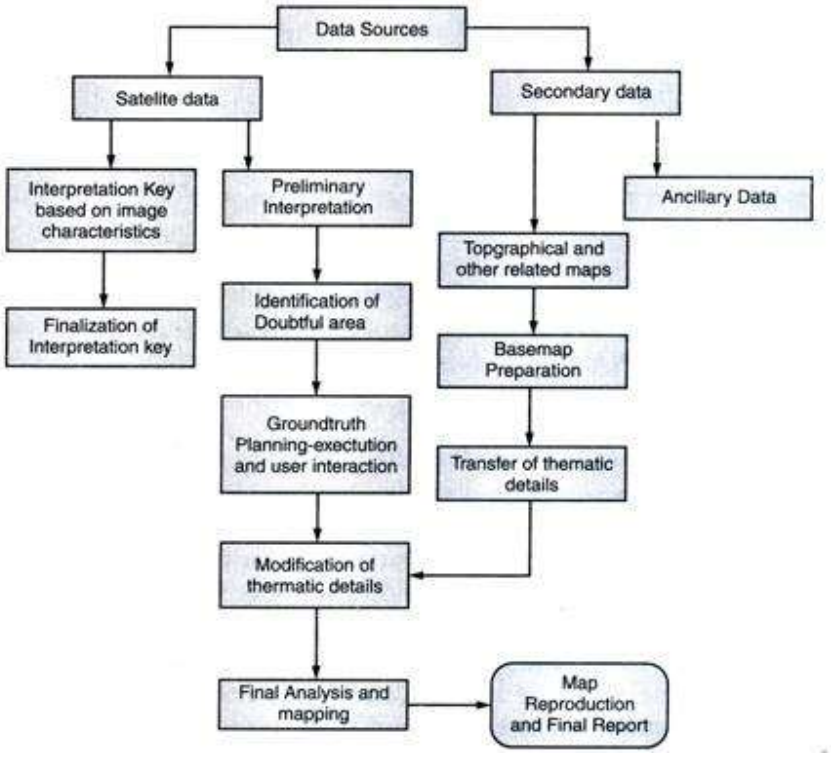


Fig. 2.10 Remote sensing and GIS for wasteland reclamation[2]

There are various ways for waste land reclamation like afforestation, reforestation, providing surface cover, mulching, changing ground to Graffiti on downhill with the help of strip farming, racing control ploughing, leaching, changing agricultural practices and ecological succession.

- Afforestation helps rejuvenated wasteland.
- Deforestation means growing the forest plants on the land where the existing plants were there which may have been destroyed by fire, overgrazing, excessive cutting, etc. It increases productivity,

[2] **Source: https://www.yourarticlelibrary.com/wp-content/uploads/2014/03/clip_image00276.jpg**

controls soil erosion as well as checks water logging. Surface cover can protect the land surface from soil erosion. As a surface cover, some crop residue can be left after the harvesting.

- Mulching is a protective cover which is of organic matter (like plants and stocks cotton) which can be used to reduce evaporation, maintain soil moisture and reduce soil erosion.
- Downhill means in running water that erodes the hill soil and soil erosion is there in order to minimise soil erosion. There are various ways to change the topography of the downhills. They are strip farming (where the earth is shaped in the form of level terrace to hold soil and water), contour ploughing (where the flowing of land is done across the hill and not in up and down style) and so on.
- Leaching is useful in the case of salt affected land where the soil salinity is more. To reduce the soil salinity, leaching them with more water can be done.
- Change in agricultural practices is an important measure where mixed cropping and crop rotation can be adopted to improve the soil fertility.
- Ecological succession is about the natural development for redevelopment of the ecosystem that helps in reclamation of the mineral deficient soil of wasteland.

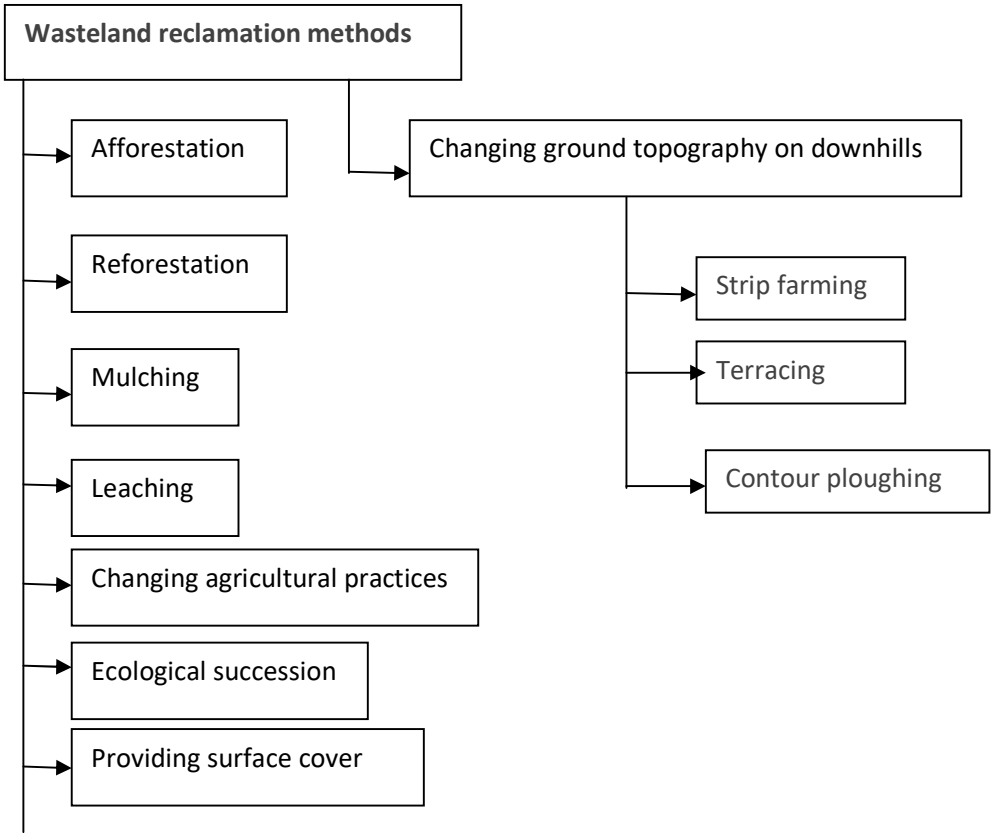


Fig. 2.11 Wasteland reclamation methods

To Do Activity

1. List down the types of wastelands and their prevalence in various states.
2. Discuss the appropriate reclamation measures of wasteland in your own state.

2.5 Rainfed Agriculture in India

Rain-dependent areas can be divided into two: 'dry grounds' get under 750 mm. of downpour a year, and rainfed regions which get rainfall in excess of 750 mm. Involving bone-dry and semi-parched biological systems, dry grounds stretch from Gujarat in the west to eastern Madhya Pradesh and from Rajasthan tol the southern tip of India.

Rainfed Areas

1. Dry land receiving <750 mm. rainfall annually, and
2. rainfed areas receiving > 750 mm. rainfall annually.

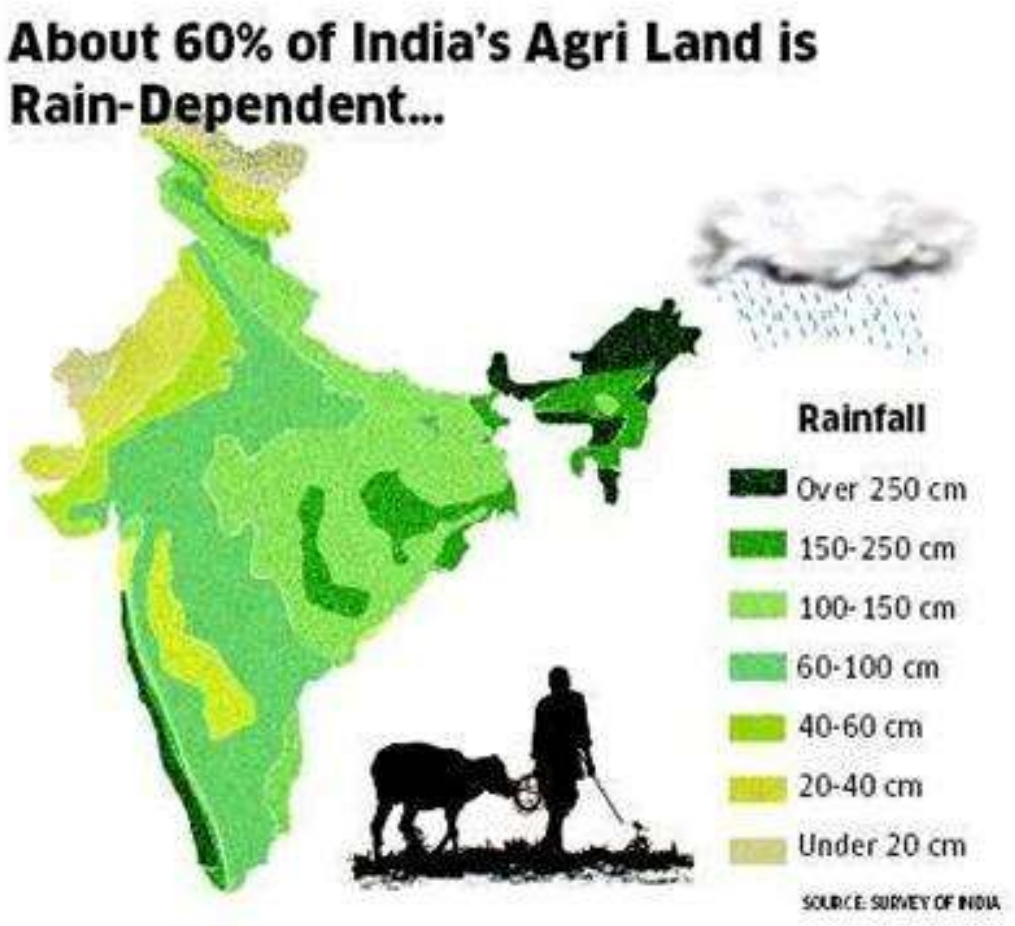


Fig 2.12 Rainfed areas[3]

[3] Source: Survey of India, https://www.drishtiias.org.in/dry-farming.html

Regarding the rainfed agriculture in India, the rain dependent area is divided into two broad categories, one dry lands where 750 mm. rainfall is received annually, and rainfed areas where more than 750 mm. rainfall is received annually. In the case of arid and semi-arid ecosystems the dry land stretches from Gujarat in the west upto eastern Madhya Pradesh and from Rajasthan till the southern end.

Basic Information about Rainfed Agriculture in India

Because of population pressure on horticultural land, there is a need to undertake rainfed agriculture. About 60 per cent of net planted area is rainfed. Climate of India in the rainfed areas is complex to cultivate the land and has nutrient deficiencies with water scarcity that adversely affects the crop production. The climate of the rainfed area is basically semi-arid and dry sub-humid with a limited wet season followed by a long dry season. Rainfall in the rainfed area is unpredictable and of less intensity.

Features of Rainfed Agriculture

In India the rainfed area is diverse ranging from the resource-rich area to resource limited area. In some of the resource rich areas are high productive and have the option of technology, while in case in resource-limited areas, there are dryness as well as constraints related to technology. In this case it becomes difficult to survive with the farm mechanism. Rainfed agriculture is practised under a wide assortment of soil types, Agro-climatic conditions and precipitation conditions ranging from 400 mm. to 1600 mm. annually. The harvests which are developed in the rainfed region that is inclined to make due into the storm during the issues because of water pressure may create, because of the variability in rain delay in showing diversity in crop management practices or there is a variety of soil.

Rainfed Farming: Crisis

There are a number of issues in the rainfed area because of the various constraints, particularly water crisis, farmers' suicides, green revolution, ground water problem, change in the cropping pattern and depletion of the groundwater level.

- **Farmers' Suicides in Rainfed area**

Rainfed farming system depends on the locally available inputs, seeds, animals, etc. With the help of inputs farmers grow many crops which can make them to survive in the desert life situation. However, in the current situation the farmers produce in rainfed areas notwithstanding limited options to produce as well as to adopt the technologies. In the meantime, farmers in the rainfed region started cultivating high value crops or they started commercializing the cash crops which require high inputs such as chemical fertilizers, pesticides, hybrid seeds, irrigation and energy. With the high cost of production for the commercialization of crops in the rainfed area, it was difficult for individual marginal farmers to mobilize the resources at their own. They were not well aware of the intercultural practices which are required for hybrid seeds as well as with the technological upgradation. All these factors influenced their psychology, social survival conditions and economic situation leading them to suicides.

- **Ground water Problem in the Rainfed Area**

At the time of the green revolution in 1960s, some issues emerged in the rainfed areas. The Green Revolution was planned and designedin such a manner that developing high yielding assortments of wheat and rice required an exceptionally high measure of water and other inputs. In the northern fields the farmers have realised that rainfed agriculture is going down and they have to adopt the hybrid varieties because the canals are there for irrigation. The story is different in the dryland area because the seeds and fertilizers were provided to the farmers but the water was not accessible. Therefore,

those farmers who wanted to adopt hybrid seeds and fertilizers found themselves under constraints. When electricity came, farmers started investing in ground water pumps. Consequently, there were tube wells which become the mainstay of irrigation. As per the Planning Commission's report Abstract of Groundwater Resources in India in 1960-61, channels and tanks represented 61 per cent of non-downpour water for the water system in contrast to 0.6 per cent for tube wells. In 2002-03 the portion of channels and tanks was down to 33 per cent, while of tube wells expanded to 39 per cent.

Change in the Cropping Patterns

In the dry areas in order to reduce the vulnerability due to the rain, some of the farmers changed the cropping patterns. They were growing crops like jowar, bajra and pulses. In coarse cereals there was low productivity but it had less effect because the farmers saved food. While in the same space they planted multiple crops such as for pulses, both from crop resistant, drought resistance and can be grown along together with the wheat. Farmers of the region where having multiple practices and diversification of agriculture they were maintaining the livestock crops if they were near by the forest area. Due to the Green Revolution, advent of electricity, groundwater and tube wells, they changed the cropping patterns.

Box 2.2 Case of changing the cropping pattern

There is an example of cropping pattern change among the farmers of Malwa in Madhya Pradesh. They were growing Malvi gehun, that is a local wheat variety, at the time of the Green Revolution. After the electricity came, they started changing their farming activities. They started to grow cash crops like soyabean that have been replaced by jowar. High yielding varieties of wheat have been displaced by the Malvi gehun. The same situation was across the country in almost all the states. They started to take the cash crops that was the main reason of the rainfed areas where cotton, maize and soyabean remain as major cash crops in the rainfed area.

Groundwater Level

In the rainfed area there is extraction of groundwater with the help of tube wells which leads to depletion of the water resources. There are various examples. In some parts of Madhya Pradesh the groundwater level has declined from 50 fts. in 1975 to more than 1000 fts. today Due to severe water exploitation, there is an acute water crisis in various states.

Box 2.3 Ratio of Ground water extraction and ground water recharge

- If the ratio of groundwater extraction to groundwater recharge is less than 70 per cent, that is considered safe extraction.
- If the ratio of groundwater extraction and groundwater recharge is 70 to 90 per cent, that is considered as a semi-critical situation.
- If it is 90 to 100 per cent, that is considered critical.
- If it is more than hundred, that situation is considered over exploitation of the

There are many states where the level of groundwater is now over exploited and it is unsustainable. There are six states which have a very critical situation of water crisis. They are Punjab, Rajasthan, Haryana, Tamilnadu, Gujarat and Uttar Pradesh. Ironically, the production of foodgrains from them accounted for half the total foodgrain production in 2008-9.

National Rainfed Area Authority

National Rainfed Area Authority was set up in 2006 to deal with the rainfed area of the nation. That was the warning body which planned with some basic rules for the watershed improvement. It framed some rules for the Watershed Development Project and has meetings with all the States for their execution.

Table 2.5 Guidelines for Watershed Development Project (Source-NRAA, 2006)

Constituents	Dryland farming	Rainfed farming
Rainfall (mm.)	< 750	>750
Moisture	Shortage	Enough/sufficient
Growing regions	Arid and semi-arid & uplands of sub-humid & humid regions.	Humid and sub-humid regions
Cropping system	Single crop or intercropping	Intercropping or double cropping
Constraints	Wind and water erosion	Water erosion

To Do Activity

Discuss various issues and crisis emerging in your state due to water crisis and rainfed agriculture.

Dry farming means cultivation of crops in the areas where annual rainfall is less than 750 mm., while dryland farming means the areas where annual rainfall is above 750 mm. The rainfed farming are the areas where the regions received more than 1150 mm. Cropping system represents the cropping pattern which is adopted in the farm and its interactions with the farm resources, other farm enterprises and available technology. It leads to the efficient use of available resources, besides reduction in the cost of production. In dryland farming there is scope for agroforestry, social forestry, silvi pasture and likewise many more practices which do not supply food but fuel to the villagers and cattle. But they form a suitable vegetative cover for ecological maintenance. Watershed management involves a judicious use of natural resources where there is active participation of Institutions, organisations and community mobilization all of which are used with the ecosystem.

Model Questions

1. Define the cropping system and its various types.
2. Explain the issues due to rainfed farming and its appropriate measures.
3. Define the wasteland and measures of its reclamation.
4. What is watershed? Discuss watershed management programmes.
5. Explain watershed management components.
6. Explain the constraints of dry land farming with corrective measures.
7. What is intercropping? Discuss its advantages and challenges.

References

Abdulai, A. and Hazell, P. (1995). The role of agriculture in sustainable development in Africa. Journal of Sustainable Agriculture 7(2/3), 101–119.

- Bhattacharyya, T., Pal, D.K. and Deshpande, S.B. (1993) Genesis and transformation of minerals in the formation of red (alfisols) and black (inceptisols and vertisols) soils on Deccan basalt in the Western Ghats, India. Journal of Soil Science 44, 159–171.
- Biswas T.D. and S.K. Mukherjee. (1994). *Text Book of Soil Science*, Tata McGraw Hill publishing company Ltd., New Delhi.
- Blanco, H and Lal, R Principles of Soil Conservation and Management, C Springer Science and Business Media B.V. 2010.
- Chandrasekaran B, Annadurai K and Somasundaram E, (2010).Crops and Crop Production, A textbook of Agronomy, New Age International (P) Limited Publishers, pp 181

- Chandrasekaran B, Annadurai K and Somasundaram E, (2010).Irrigation and Water Management A textbook of Agronomy, New Age International (P) Limited Publishers.
- DFID (Department for International Development). (2002) Better livelihoods for poor people: the role of agriculture. Issues Paper. DFID Rural Livelihoods Department, London, UK (Consultation Document Draft A4).
- Doorenbos I and W.O. Fruitt, (1977). *Crop water Requirement*. FAO Irrigation and drainage paper, Vol-24.
- Gupta, R.K. and Abrol, I.P. (1990) Salt-affected soils: their reclamation and management for crop production. In: Stewart, B.A. (ed.), Advances in Soil Science, Vol. II. Springer-Verlag, Berlin, Germany, pp. 223–288.
- https://www.ssiast.com/activities/watershed-management.aspx
- Rainfed areas, Survey of India**,** retrieved from https://www.drishtiias.org.in/dry-farming.html
- Remote sensing and GIS for watershed reclamation retrieved from https://www.yourarticlelibrary.com/wp-content/uploads/2014/03/clip_image00276.jpg
- Sehgal, J.L. and Abrol, I.P. (1994). Soil Degradation in India: Status and Impact. Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi, India.
- Valdemar Hercilio de Freitas (2000), *Soil management and conservation for small farms, Strategies and methods of introduction, technologies and equipment*, A joint publication Land and Plant Nutrition Management Service FAO Land and Water Development Division and Agricultural Engineering Branch FAO Agricultural Support Systems Division, Experiences from the State of Santa Catarina, Brazil, FAO SOILS BULLETIN 77, ISSN 0253-2050
- Watershed management programmes retrieved from : https://www.ssiast.com/activities/watershed-management.aspx

Chapter 3 Resource Management

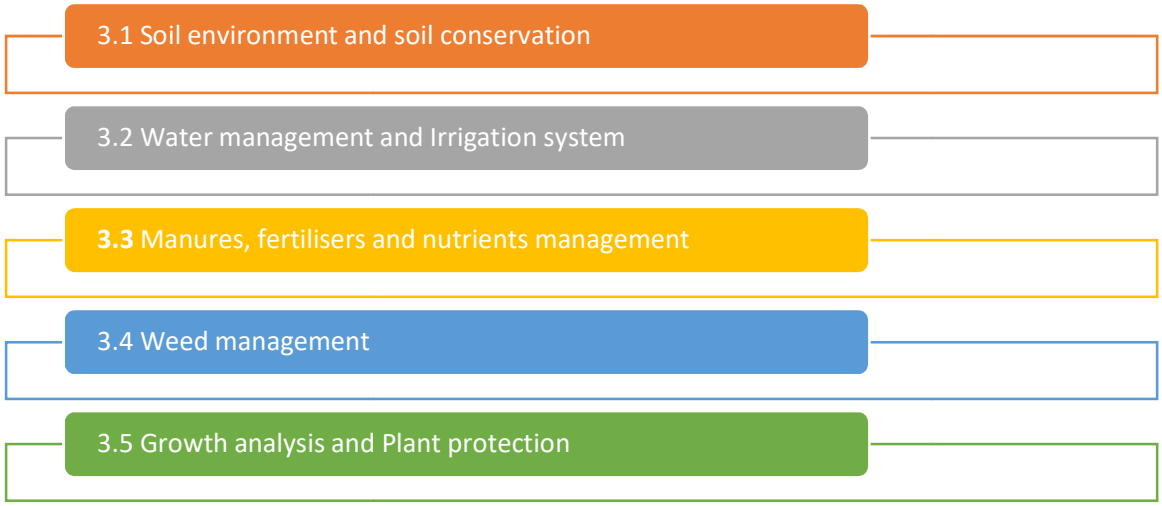
Introduction

Multiple resources are required for growth of crops such as land, water, soil, etc. It also depends on the aerial and soil environmental conditions. Soil environment can be altered by multiple methods like tillage, fertilizers applications, irrigation facilities, reduced mechanical resistance, provision of nutrients and water. Environment can be studied under various components like chemical, physical and biological. The favorable soil chemical environment is higher nutrient availability which is required for proper growth. Irrigation is one of the important determinants of plant growth as water is essential for protoplasm. It is also required for the translocation of nutrients as well as the dissipation of heat. Water is depleted due to the process of evaporation from the soil surface, transportation from the leaf surface as well as the population into the soil beyond the root zone. Irrigation is one of the important aspects of plant life which is the application of water to the soil. Rainfall is necessary for crop production also. Plants require some of the chemical elements which are considered essential elements that are consumed by the roots essentially as inorganic particles. Resource management in the case of plant growth is one of the significant mechanisms whereby we get from the environment what is needed to maintain the soil quality as well as to reduce insect/pest infestation and weed management.

Objectives

- To explain the soil environment and conservation practices.
- To examine water management and irrigation system.
- To explain the nutrients, fertilizers and integrated nutrient management.
- To explain weed management and control methods.
- To explain the Integrated Pest Management Programme and plant protection measures.

Chapter Structure



3.1 Soil Environment and Soil Conservation

Soil environment can be classified based on various conditions such as physical, chemical and biological. Soil classification is based on the proportion of predominant size fraction of sand, silt and clay. Soil texture classes are called the Textural Triangle.

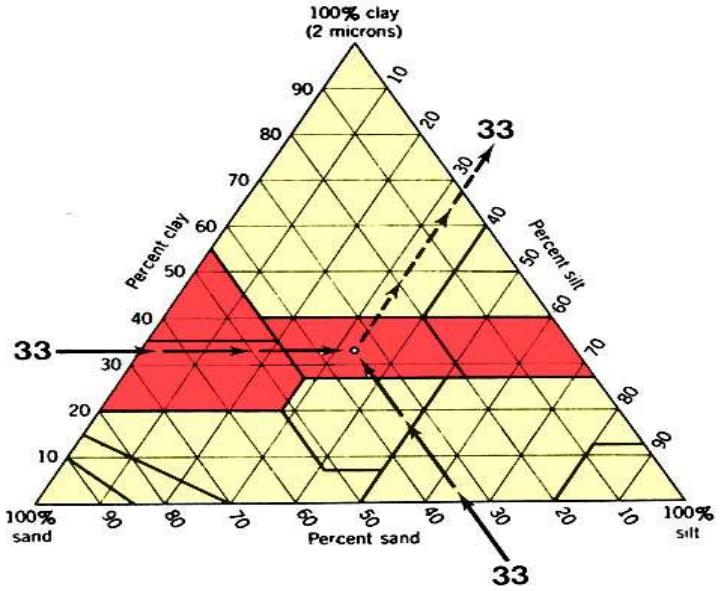


Fig. 3.1 Triangular diagram of the basic soil textural classes (Source: USDA particle sizes).

Significance of soil texture is that it is a permanent feature of soil and its changes over a period are negligible. Soil texture affects its physical and chemical properties such as water holding capacity, nutrient availability, the compressibility of soil thermal, bridging of soil nutrient fixation and drainage. It is especially about the soil particle that is sand, silt and clay which are grouped in the form of aggregates.

Table 3.1 USDA particle-size classification

Common names of soils (general texture)	Sand	Silt	Clay	Textural class
Sandy soils (coarse texture)	86-100	0-14	0-10	Sand
	70-86	0-30	0-15	Loamy sand
Loamy soils (moderately coarse texture)	50-70	0-50	0-20	Sandy loam
Loamy soils (medium texture)	23-52	28-50	7-27	Loam
	20-50	74-88	0-27	Silty loam
	0-20	88-100	0-12	Silt
Loamy soils (moderately fine texture)	20-45	15-52	27-40	Clay loam
	45-80	0-28	20-35	Sandy clay loam
	0-20	40-73	27-40	Silty clay loam
Clayey soils (fine texture)	45-65	0-20	35-55	Sandy clay
	0-20	40-60	40-60	Silty clay
	0-45	0-40	40-100	Clay

Soil structure is important because it influences soil environment and its porous space availability of plant nutrients, water holding capacity and growth of microorganisms. Soil is very dynamic and depends on various factors such as clay minerals, cation and anion exchange capacity and pH of soil. pH is the

negative logarithm of hydrogen ion activity which indicates the acidity and alkalinity of the soil. Nutrients in the soil determine the physical, chemical and biological changes or transformation in soil.

The biological environment is composed of several micro-organisms that belong to plants as well as the animal kingdom. The activity of soil organisms can be changed by managing various practices within the soil environment for plant growth. Soil organisms in flora and fauna are divided into microflora and microfauna. Microorganism secretes several enzymes such as sulfatase, phosphatase, cellulose and proteinase which are utilized for the breakdown of complex compounds.

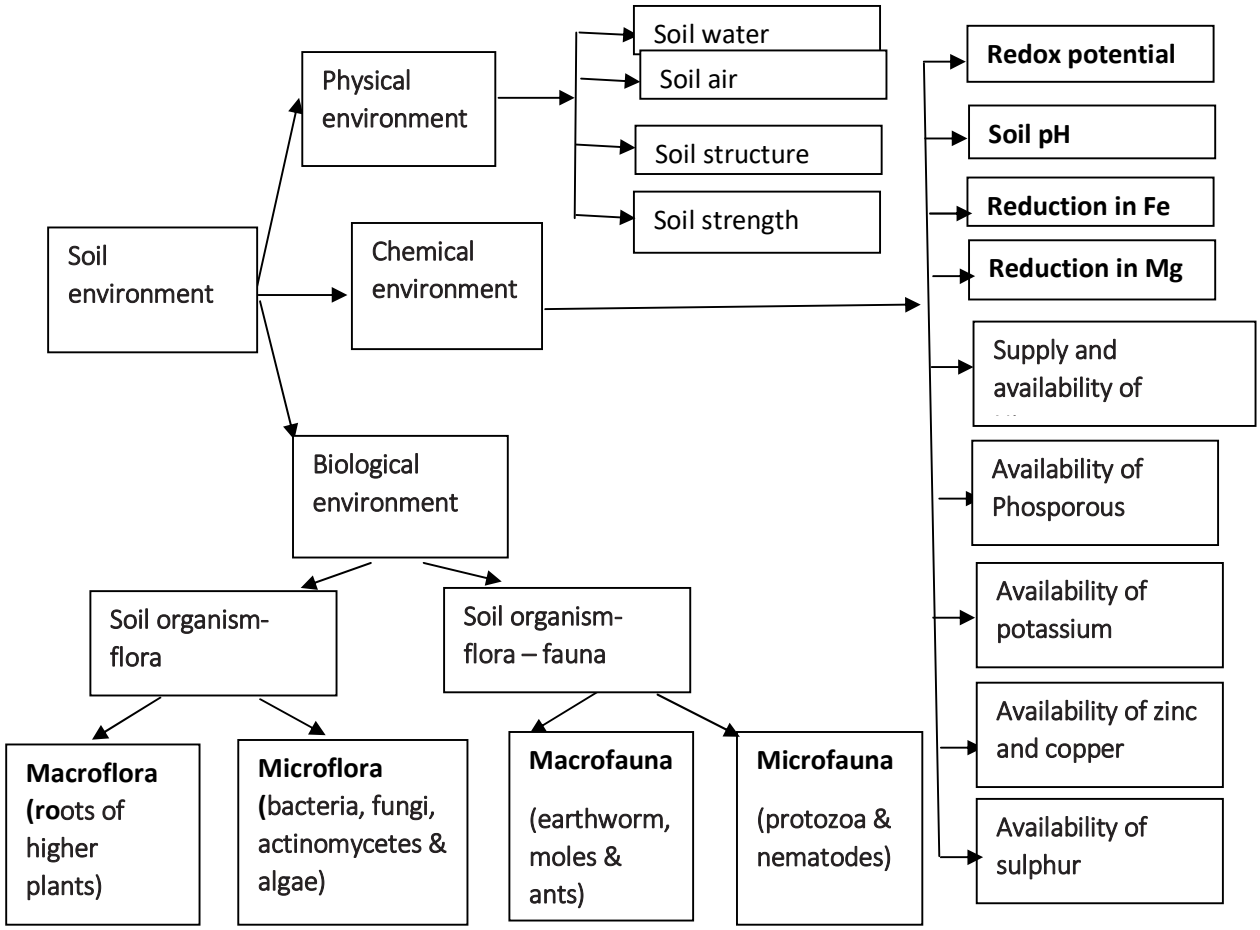


Fig. 3.2 Soil Environment classification

Soil conservation is the cycle of separation of soil particles from the parent body and transportation of isolates of soil molecules by wind or water. The segregating agent for soil particles is falling raindrops, flow and wind. Various factors cause soil erosion such as rainfall, type of vegetation and soil which influence erosion. High-intensity rainfall of long duration causes erosion. The impact of raindrops is absorbed by the vegetation present on the soil surface and therefore, more breakdown of soil aggregates and it depends on the type of vegetation, porosity, height, rainfall and precipitation. Soil characteristics, degree and length of the slope also determine the amount of runoff as well as the extent of erosion. The physical properties of soil like soil structure and texture influence the detachable ET as well as transportation of soil particles. Higher exchange capacity, calcium and magnesium cation

exchange have favorably influence on soil structure and are less susceptible to illusion, while soils with high salt and sodium content are more susceptible which causes soil dispersion.

Soil preservation utilizes and oversees land-based capacities of the land which include the use of best practices without harming the land. There are different methods of soil protection.

- Land utilization dependent on its ability.
- Conservation of soil and keeping away from harm to soil.
- Rectification of acridity, alkalinity and seepage.

Soil and water preservation is fundamental for the supported efficiency of land. The motivation behind soil and water protection is to:

- Promote the correct utilization of land,
- Prevention of soil disintegration,
- Restoration of the efficiency of disintegrated land,
- Maintenance of soil efficiency,
- Control of spillover and
- Regulation of water assets to the water system and seepage.

Land Degradation

Soil degradation is the reduction in the potential and diminished capacity of any land which is beneficial for humanity. There are various causative factors for land degradation such as:

- Improper land clearing methods,
- Soil compaction from mechanization,
- Acidification,
- Crop intensification,
- Wrong use of fertilizers,
- Salinization,
- Organic matter,
- Soil biota desertification

Soil Erosion

There are numerous operators for causing soil disintegration which is wind and water. Soil is comprehensively grouped into land or common or ordinary disintegration and another is quickened disintegration.

- Geological disintegration can happen normally where is soil is changing into the residue. Soil disintegration is adjusted by the cycle of soil development.

Soil erosion by water- Soil erosion by water occurs in three stages, the process is called detachment, transportation and deposition. There are various types of water erosion such as splash erosion, sheet erosion, gully erosion, integral erosion and landslide. Various factors influence soil erosion by water such as climate, rainfall, soil and its characteristics, presence of vegetation, presence of crop forest, vegetation management, topography of the land, human behaviour as well as land exploitation.

Soil erosion by the wind- In this case process of detachment, transportation and deposition of soil material by wind takes place. There are various types of soil erosion. Suspension happens when exceptionally fine earth and residue particles are lifted into the breeze which tend to be tossed to air with different particles by the wind itself.

- Saltation is a process in which fine particles of 2.5 mm. in diameter are lifted from the soil surface by turbulence. Saltation is the case when the major fraction of soil is moved by the wind. In this case, all particles move in the process of saltation and can cause serious damage to the soil surface as well as vegetation. Various factors affect wind erosion such as soil moisture, height, wind turbulence, surface roughness, soil properties, vegetation and length of the exposed area.

Methods of Soil Water Conservation

There are two methods by which crop damage can be reduced due to drought. These methods are:

- conservation as much water as possible in the soil, and
- the second method is irrigation.

There are some agronomic practices to conserve the soil water erosion. These are the production of evaporation from the water surface, reduction of pollution from the soil surface, utilizing store water efficiency, reduction of seepage, losses from reservoirs and reduction of the percolation losses from cropland.

- In the case of a reduction of evaporation from water surfaces, covering the water surface with barriers that prevent vaporization, blocking rafting that are capable of floating and sand and rockfill dam are the ways.
- In the case of a reduction of seepage from losses from the reservoir, some of the methods are contacting the soil as well as chemical treatment of soil covers such as plastic sheet rubber.
- A reduction of evaporation from soil surface can be achieved with the help of covering it with a large amount of the water light, water retardant mulches as well as putting wind brakes or trees and fences to reduce the wind velocity.
- Percolation losses can be more in the case of a humid region where elevated agriculture is practised. These losses can be reduced by using plastic sheets and a thick layer of compost manure.
- In case of utilizing stored water efficiency, reduce the losses of water by reduction of transpiration losses, use of windbreak, plantation of optimum seed rate and growing crops which utilize water efficiently.

Soil Profile and Texture

Soil development is a process caused by climate, weathering and living matter which acting upon parent material and condition which occurs over a period. There are multiple layers in the soil profile that is called Horizon with distinctive features, structure, color and properties.

- Soil surface can profoundly affect numerous properties, most significantly physical properties. The soil surface is an after effect of the enduring cycle and physical and concoction breakdown of rocks and minerals. Because weathering is a slow process, it takes time and so soil texture remains constant and doesn't change.
- Soil colloids are the finer size fractions of the soil (clay and organic matter) which are also considered as the most chemically active portion of the soil because of their large surface area and the chemical structure of the materials involved.
- Soil structure is the arrangement as well as binding of the soil particles together in two large clusters that are called aggregate or peds.
- Soil porosity is another important soil process that takes place in the soil force, soil texture and structure that influence porosity by determining the size, number and inter-connections of pores.

Regarding the water and plant relationship, soil texture and properties like porosity affect directly the water and moment in the soil with subsequent effects on the plant growth. Chemical properties of soil include exchange capacity soil, pH, salt-affected soils, calcareous soils, etc.

The ion exchange capacity of soil- It is a measure of the ability of an insoluble material to undergo displacement of ions previously attached and loosely incorporated into its structure by oppositely charged ions present in the surrounding solution. Most chemical interactions happen in the soil in collide surfaces because they are charged surfaces. In the case of fine-textured soil, it has a great exchange capacity than the coarse because it has higher proportions of colloids.

2 types of ion exchange capacity- **a.** Anion exchange capacity (AEC) represents the positive charge available to attract anions in solution. **b.** Cation exchange capacity (CEC) is the total capacity of a soil to hold exchangeable cations. CEC is an inherent soil characteristic and is difficult to alter significantly. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification. In most soils CEC > AEC.

Soil pH is a soil acidity or alkalinity. It is a measure of hydrogen ion of the soil, and affects the cation exchange and anion exchange capacities by changing the surface charges of colloids. Therefore, at high (alkaline) pH values, the hydrogen ion concentration is low. Most soils have pH values between 3.5 and 10. In higher rainfall areas the natural pH of soils typically ranges from 5 to 7, while in drier areas it is 6.5 to 9.

Salt affected area can adversely affect the function and management of the soil which include mostly in the arid and semi-arid regions where evaporation is more than the precipitation and dissolved solids are left behind to accumulate in an area where there is an elevation and changes have caused the salt to reach down and accumulate in low-lying places. There are three salt-affected soils: Saline, Sodic, and Saline sodic. Saline soils have a high amount of soluble salts such as calcium, magnesium and potassium, while in sodic soils is dominated by sodium. Saline sodic soil has both high salt and sodium.

Calcareous soil is dominated in northern great plains and has more calcium and magnesium carbonate. It affects the soil properties related to plant growth, whether they are physical such as soil -water relations and soil crusting, or chemical such as the availability of plant nutrients. Cultivation of calcareous soils presents many challenges such as low water holding capacity, high infiltration rate, poor structure, low organic matter (OM) and clay content, low CEC, loss of nutrients via leaching or deep percolation, surface crusting and cracking, high pH and loss of nitrogen (N) fertilizers. That is why it is important to consider the presence of carbonates before analyzing the soil texture as a calcareous soil both in field as well as laboratory.

The soil profile is a three-dimensional section of the soil that includes various Horizon layers. Out of all these layers, the physical, chemical and biological characteristics of soil vary. Origins of different soil-forming factors like drainage, freezing and management as well as result are in great variance in the appearance of the soil. Soil Horizons can be defined as the individual layer within the soil profile and each profile consists of at least one Horizon which can be divided as topsoil, subsoil and rock. Soil profile which can be divided into three classes according to the level of texture changes vertically down.

To Do Activity

1. Discuss the soil profile and texture of your location and map on the basis of soil texture.
2. What are the factors for soil erosion in your region? Find out conservation practices.

Soil Conservation Practices

Such practices can be a tool for the farmers to reduce soil degradation as well as double organic matter. Several practices model for soil conservation such as crop rotation, reduced tillage, mulching, cover cropping, cross-slope farming, etc.

- Crop rotation enables farmers to increase soil's organic matter content, soil structure and rooting depth. It is accomplished by growing secondary crops that enhance soil health.
- Cover cropping and mulching are effective in reducing soil erosion by leaving a cover over the soil which reduces soil displacement associated with the impact of raindrops hitting soil particles. They also reduce the volume and velocity of runoff over the soil. Mulching consists of applying organic material over the exposed soil. Hay makes the best mulch, but it is important to ensure that it is harvested before weeds mature. Straw can also be used.
- Conservation Tillage is a field operation aimed at preserving soil aggregates, organic matter and surface residue from previous crops.
- Cross-slope farming is the practice of conducting field operations perpendicular to the field slope. It is an effective method to control large volumes of runoff that flow over a field. Other soil conservation practices can be effectively integrated with cross-slope farming.
- Buffer strips are vegetative areas that separate field boundaries from watercourses. They are effective in stabilizing stream banks with their extensive root system. They are also efficient at preventing soil and contaminants from entering watercourses by providing an area for field runoff to collect.

3.2 Water Management and Irrigation System

Irrigation is a process where the artificial application of water is given to the soil for crop production to supplement the rainfall and groundwater. There is importance of delegation to the plants which contains 90% water which gives turgidity which is an essential part of transportation as well as protoplasm and maintaining the balance of temperature of the plant. Crops draw water from moisture which is stored into the soil. But when the presence of water in the soil is low, the plant's requirement is met artificially. The upper limit of the optimum soil moisture range is the field capacity and the lower limit is just above the wilting point. The purpose of irrigation is to store the water in the soil between these limits.

Since the plant dries due to lack of water from evaporation and transpiration, plants start wilting during the daytime and become normal at night. This condition is called a wilting coefficient. The latter is defined as the percentage of water content of soil when the plants growing in that soil are first reduced to a wilted condition from which they cannot recover in an approximately saturated atmosphere without the addition of water to the soil. There are various methods of irrigation, i.e.,

- surface,
- subsurface and
- pressurized irrigation.

There are multiple criteria for the selection of irrigation methods as water supply sources, topography of the plot, quantity of water to be applied, kind of crop as well as the method of cultivation. Surface irrigation methods include border irrigation, check basin irrigation and furrow.

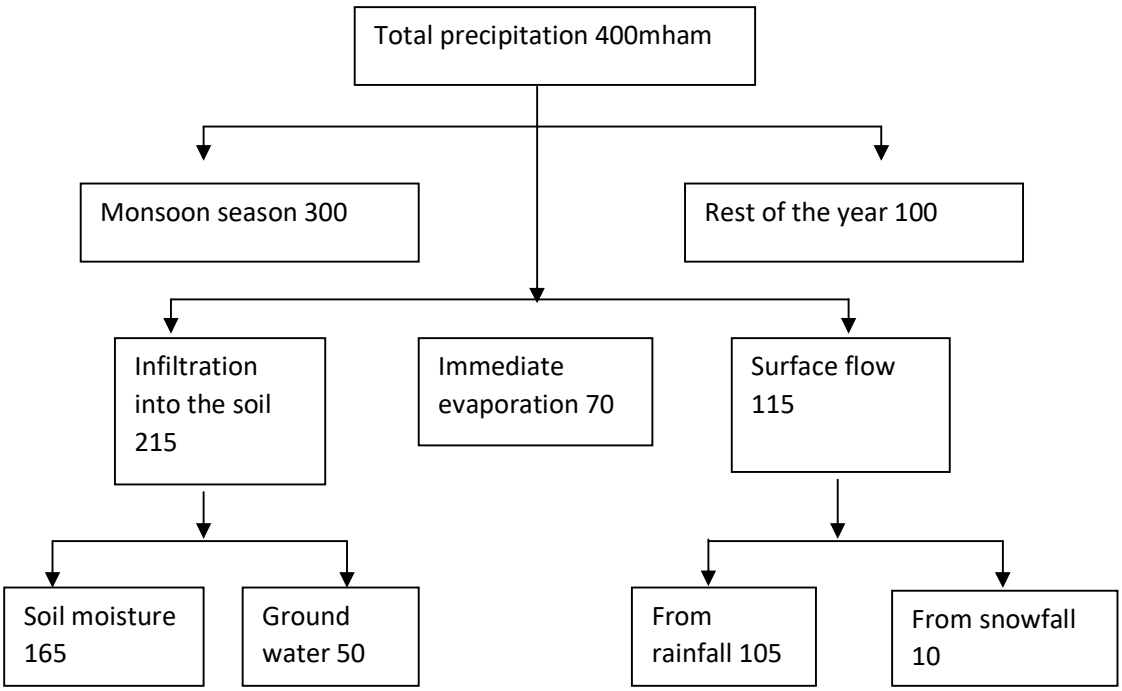


Fig. 3.3: Water resources in India

Source: Irrigation Commission of India (1972)

Types of Irrigation

There are various types of irrigation methods. The major methods are surface irrigation, sprinkler irrigation and trickle irrigation. The purpose of providing various types of irrigation methods is to apply an adequate amount of water to the crop so that water can uniformly apply all over the crops and avoiding the unnecessary wastage as well as ensuring that there is no long-term problem such as salinity or soil erosion.

For the selection of the best method of irrigation, the important to understand the crop-soil-water conditions as well as the maintenance and method used by the farmers. Technical consideration of irrigation may include soil infiltration rate, soil water holding capacity, crop, climate, cost, capital and operating cost, water supply quantity and quality, as well as labour cost.

- Surface irrigation includes basin irrigation, border irrigation and furrow irrigation. Surface irrigation is a common method of irrigation which accounts for almost 95% of irrigation in the world. Surface irrigation methods are often selected because they are simple and can be used by farmers with little or no knowledge of irrigation.
- Basin irrigation is one of the simplest and commonly used methods in surface irrigation. In this case, basins can be adopted which is suitable for most of soils and farming practices, and a wide range of crops can be grown in a small basin. Basin can be constructed primarily for flooded rice and now it is increasingly used for diversified cropping.
- Border irrigation is less popular and done where the rectangular-shaped and suitable large farms exist.
- Furrow irrigation is the most widespread method for row crops. It is practiced where the slope of the land is up to 2% in arid climate, while it is restricted to 0.3% in the humid areas because

there's a lot of risk of erosion due to intensive rainfall. It may be useful to reduce the cost of irrigation and drainage, and it makes mechanization.

- Sprinkler irrigation is used in approximately 5% of the irrigated area. It is a method of applying irrigation water that is similar to rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air and irrigation donein the entire soil surface through spray heads so that it breaks up into small water drops that fall to the ground. Sprinkler irrigation is simple to operate requiring little water management skills. It is better for places where there are large farmers as in many developing countries.

Table 3.2 Technical Factors Affecting Selection of Irrigation Method

Irrigation Method	Crops	Soils	Labour (h/ha/irrigat.)	Energy demand	Potential efficiency (%)	Capital cost
Surface					60	low
• Basin	All crops	Clay, loam	0.5 - 1.5	low		-
• Border	All crops except rice	Clay, loam	1.0 - 3.0	low		-
• Furrow	All crops except rice and sown/drilled	Clay, loam	2.0 - 4.0	low		-
Sprinkle	All crops except rice	Loam, sand	1.5 - 3.0	high	75	Medium
Trickle	Row crops & orchards	All soils	0.2 - 0.5	medium	90	High

Source: Food and Agriculture Organization of the United Nations, Department for International Development.

- Trickle irrigation is the least used system in the word scale which involves less than 4.1% of irrigated land. There are multiple claims which are made for trickle irrigation such as it is not the water-saving method. There is a misunderstanding about its efficiency. But its potential is 90% and the actual efficiency like a surface and sprinkler irrigation will depend on a large extent on the farmer and the pattern of utilization of equipment. It is well suited to a small farm. So it is used in India where farmers have gone in for surface irrigation.
- Micro-irrigation is defined as the frequent application of small quantities of water directly above and below the soil surface; usually as discrete drops, continuous drops, or tiny streams through emitters placed along a water delivery line. Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation.

Irrigation Water Management

Irrigation water management is for the prevention of excessive use of water for irrigation. The purpose is preventing aggregation-induced frozen, reduce labour, minimizing pumping cost, maintaining or improving quality of groundwater and downstream surface water as well as increased crop biomass and product quality. There are various tillage practices and crop rotations to assist irrigation in applying proper irrigation water management. The latter is the act of timing and regulating irrigation water application in a way that will satisfy water requirement of the crop without wasting water, energy and plant nutrients or degrading the soil. This involves applying water according to crop needs in amounts that can be held in the soil and at rates consistent with its intake characteristics. A primary objective is to give irrigators an understanding of conservation principles by showing them how they can judge the

effectiveness of their irrigation practices, make good water management decisions and recognize the need to make adjustments in the existing systems or to install new systems. Proper irrigation water management:

- Prevents excessive use of water
- Minimizes pumping costs
- Prevents excessive soil erosion
- Reduces labour
- Maintains or improves the quality of groundwater and downstream surface water
- Increases crop biomass yield and product quality

Irrigation scheduling is a part of proper irrigation water management that involves decisions like when to irrigate and how much water to apply. Scheduling tools provide information that irrigation decision-makers can use to develop irrigation strategies for each field. Such strategies may be based on long-term data that represent average conditions or may be developed as the season progresses, using real-time information and short-time predictions. In both cases, information about the crop, soil, climate, irrigation system, water deliveries and management objectives must be considered to tailor irrigation scheduling procedures to a specific irrigation decision-maker and field condition. An irrigation scheduling tool needs be accurate enough to make the decision when and how much to irrigate.

Soil water evaporation is due to transportation from the soil surface. Transportation of water to the plant surface has deep circulation into the soil beyond the root zone. About 97% water is present in the ocean and that is not useful for irrigation. Out of the total quantity of water, only 2.6% water is freshwater while 77.23% is the polar ice cap and glaciers. Only a very small fraction of water can be used as a resource on earth which is available in the ground, lakes, rivers and atmosphere which can be harvested for the irrigation of crops. Regarding the water sources of India, the average rainfall is 1194 mm. which is over an area of 3.28 million hectares, and that rainfall amounts to 392 million hectares.

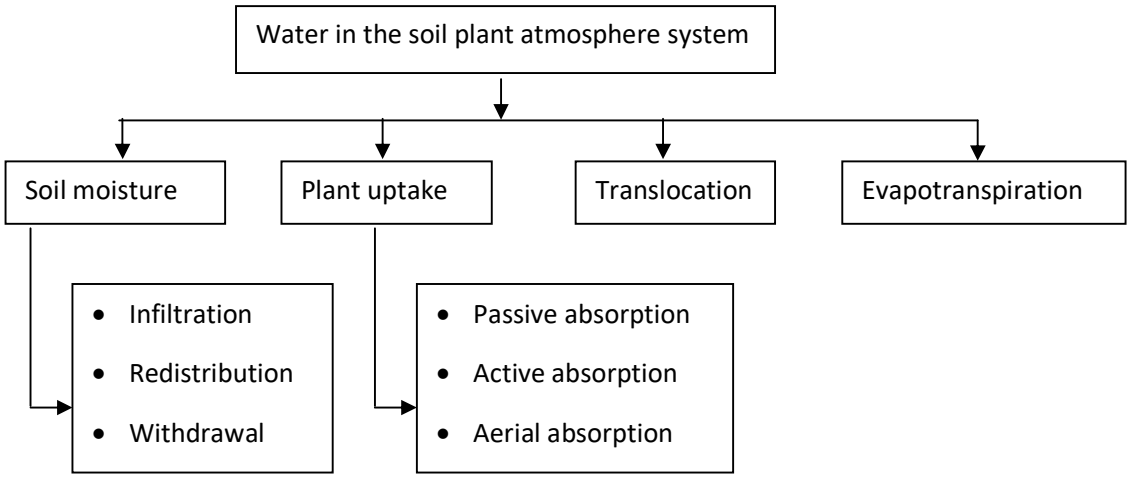


Fig. 3.4: Steps in water movement in the soil plant atmosphere system

Water movement in soil includes three phases, viz., infiltration, redistribution and withdrawal. It may be downward, depending on the difference in water potential in different parts of soil below the depth of 5 to 10 cms. The vapor pressure is generally greater than that of the atmosphere in the daytime and the

solar energy is absorbed by the shallow layer of soil which becomes warmer than the atmosphere. Above and underline the soil layers water vapor moves upwards from the surface layer in the atmosphere and downward into a cooler layer where it condenses.
The movement of water within the soil is a highly complex phenomenon due to the variations in the states and directions in which water moves and the variation in the forces that cause it to move. Generally, three types of water movement within the soil are recognized – saturated flow, unsaturated flow and water vapor flow.

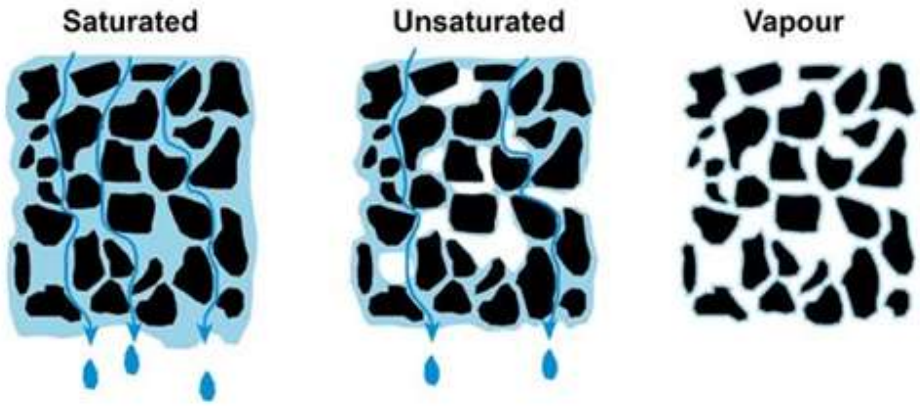


Fig. 3.5: Different types of soil water movement

The water in the liquid phase moves through the water-filled pores within the soil (saturated condition) under the influence of gravitational force. Water exists as thin films surrounding the soil particles (unsaturated condition) which move under surface tension. Water in the vapor form diffuses through air-filled pores along the vapor pressure gradient. In all cases, water flow is along the energy gradients, i.e., from a higher to lower potential.

The saturated flow of water occurs when all pores are filled with water either due to rain or irrigation in water locked conditions. There is a flow of liquid water because of a gradient in matric potential from one region to another region. The direction of flow of water is from a higher potential to lower potential. There is a lateral movement that occurs mainly due to the matric potential, the rate of movement depending on hydraulic conductivity of soil which can be expressed through

$$V = k f$$

Where V is the volume of water moved per unit time,
k is the hydraulic conductivity and
F is a water moving force.

- In the case of saturated soil, the hydraulic conductivity is constant and depends on the size and configuration of the soil pores. The flow rate of soil force is proportional to the fourth power of the radius. If the size of the pores is higher, then more rapid and saturated flow occurs, while in case of sandy soil which is having higher conductivity due to the presence of higher macropore space compared to the Clay soil. When a soil is saturated, its pores are water-filled and conducting. The water phase is then continuous and the conductivity is maximal. When the soil desaturates, some pores become air-filled so that the conductive portion of the soil's volume diminishes.

Table 3.3 Water movement in the soil

Particulars	Saturated flow	Unsaturated flow	Vapour movement
Major force	Gravitational	Metric	Vapour pressure
Water form	Liquid	Liquid	Vapour
Major direction of flow	Downward	Lateral	All directions
Pore space	All pores filled with water	Micropores filled with water	All pores are empty
Rate of flow	Fast (1cm-100cm/day)	Slow ((0.01 cm to 0.00001cm/ day)	-
Volume of water movement	Large quantities (375000kg/ha in 15 cm depth)	Small (1,00,000kg/ha in 15cm depth of soil)	Negligible (15kg/ha in 15 depth of soil)

- In the case of unsaturated flow, larger pores in soil are filled with air, while smaller pores hold and transmit water. The contribution of the hydraulic head or the gravitational component to total potential becomes progressively less.
- Vapour movement- When soil becomes dry, water from microspores is also empty and water is mainly present in the form of water vapor that moves from one's own zone to another due to water vapor pressure gradient from higher vapor pressure area to the low vapor pressure area.

Evapotranspiration is a process where the evaporation happens from the surface of the soil or free water surface with the help of the diffusion process by which water in the form of vapor is transferred to the atmosphere. There are two steps involved in vapor transpiration where water is the first transfer from liquid to vapor and then the vapor is transported from the evaporating surface into the atmosphere. Transpiration is a process where water vapors leave the living plant body and enter the atmosphere in an evaporator process. There are two aspects of soil water, viz., there are amounts of water present in the unit mass or volume of soil and the energy status of water in the soil is important in plant-water relationship.

Irrigation Efficiency

Irrigation efficiency (IE) is the ratio of the amount of water consumed by the crop to the amount of water supplied through irrigation (surface, sprinkler or drip irrigation). The losses of irrigation water that can occur in the field are convenience runoff, evaporation and percolation. The efficiency of irrigation is increased by reducing these losses. At the field level, water system productivity can be expanded by choosing appropriate techniques for the water system, lacking area planning and connecting with and proficient irrigator. Irrigation efficiency is helpful to indicate how efficiently the available water can be supplied.

$$Ei = Wt + Ws - Re / Wi \times 100$$

Where Ei is irrigation efficiency (per cent),

Wt the volume of irrigation ware per unit area of land transpired by plants evaporated from the soil during the crop period (including field preparation and nursery),

Ws- the volume of irrigation water per unit area of land to regulate the salt content of soil solution,

Re- effective rainfall and
Wi- the volume of water per unit area of land that is stored in a reservoir or diverted for irrigation.

Conveyance Efficiency

Conveyance efficiency is the ratio of the volume of water delivered for irrigation to the volume of water placed in the conveyance system. This ratio is normally less than 1.0 for open channel conveyance systems, but it may be approximately 1.0 for pipeline conveyance systems.

$$Ec=Wf/Ws \times 100$$

Where Ec- water conveyance efficiency (per cent),
Wf-water deliver at the field and
Ws-water deliver at the source.

Water Application Efficiency

It refers to the irrigation water applied to the field that is lost due to the surface runoff and percolation. It is a measurement of how effective the irrigation system is in storing water in the crop root zone. It is expressed as the percentage of the total volume of water delivered to the field that is stored in the root zone to meet crop evapotranspiration (ET) needs.

WAE=water stored in the root zone/water delivered to the field X 100

Source: Chandrasekaran, Annadurai and Somasundaram (2010)

Water Storage Efficiency

It is the ratio of the water stored in the root zone during irrigation to the water needed in the root zone before irrigation.

Water storage efficiency= water stored in the root zone during irrigation/water needed in the root zone before irrigation X 100.

Source: Chandrasekaran, Annadurai and Somasundaram (2010)

Water Use Efficiency

It is defined as the yield of marketable crop products as per unit of water used in evapotranspiration.

$$WUE=Y/ET$$

Where WUE- water use efficiency (Kg/ha mm of water),
Y-the marketable yield (kg/ha) and
ET-evapotranspiration (mm.).

Various practices and factors are responsible to increase water use efficiencies such as the plant climatic conditions, soil moisture, fertilizers and plant population.

Crops and their Water Requirements

Table 3.4 Crops and their water requirements

Crop	Water requirement (mm.)	Grain yield (kg./ha)	WUE(kg/ha mm.)
Rice	2000	6000	3.0
Sorghum	500	4500	9.0
Peral millet	500	4000	8.0
Maize	625	5000	8.0
Groundnut	506	4680	9.2
Wheat	280	3534	12.6
Finger millet	310	4137	13.4

Weather affects evapotranspiration. Manipulation of climate up to an extent is not possible but evapotranspiration can be reduced by mulching, use of anti-transpirants, etc., that are more economical and practised.

Soil moisture content- When there is inadequate soil moisture as well as excessive water supply to the crop both plant growth and productivity are adversely affected. For every crop and combination of environmental conditions, there is a narrow range of soil moisture levels which affects water use efficiency when there is a higher than the less or greater supply of water. Plant population also indicates the water use efficiency such as higher yield potential made possible by a favourable water moisture level provided by irrigation and soil fertility, lower level resulting from the heavy application of fertilization and genetic potential of a new variety of crop and hybrids.

Crop Water Requirement

It is the water required by the plants for their survival, growth and to produce the production. It can be defined as the quantity of water required for the crop during a period for its normal growth under field conditions. There are many sources of water for irrigation such as well, artisan, canal and river.

$$WR = T + E + WP + WL + WSP$$

Where transpiration is lost through leaves (T)

Evaporation Loss through soil surface in the trimmed region (E)

The measure of water utilized by plants (WP) for its metabolic exercises is assessed as less than 1% of the all-out water ingestion.

Other application losses are conveyance loss, percolation loss, runoff loss, etc (WL).

The water is also required for particular reasons like puddling, furrowing, land planning, draining prerequisites, leaching, dissolving fertilizers and chemicals.

However, the idea about crop water requirement is important for planning of the farm concerning the total quantity of water which is required and its efficient use for various crops schemes. A combination of losses of evaporation and transpiration from a crop field is termed Evapotranspiration which is considered as a part of water requirement.

To Do Activity

Discuss the major crops grown in your region per hectare and find out the water use efficiency (WUE) for the crops.

Irrigation Scheduling

Irrigation scheduling is the process used by irrigation system managers to determine the correct frequency and duration of watering. Water system booking is a dynamic cycle commonly in every year which includes when to inundate how much water is needed to meet every standard impact, and the amount and nature of the yield. It shows how much water in the water system is required and how frequently it should be given. Abundant water in the water system is likewise undesired since it squanders water. Below root zone excess irrigation can mean loss of fertilizer nutrients which can cause water stagnation and salinity, ultimately damaging the crop. Irrigation scheduling is important for irrigation engineers, social scientists and economists as it helps to cover more area with available quantity of water or to satisfy the whole command area from head to tail in the canal or river system. In the soil of the forest too irrigation scheduling should not be over delegated or underrated because in both the conditions it can spoil the chemical and physical equilibrium of the soil. For agronomic delegation, scheduling is important to get the use of per unit quantity of water in a normal situation as well as to protect the crop to get it as much as possible.

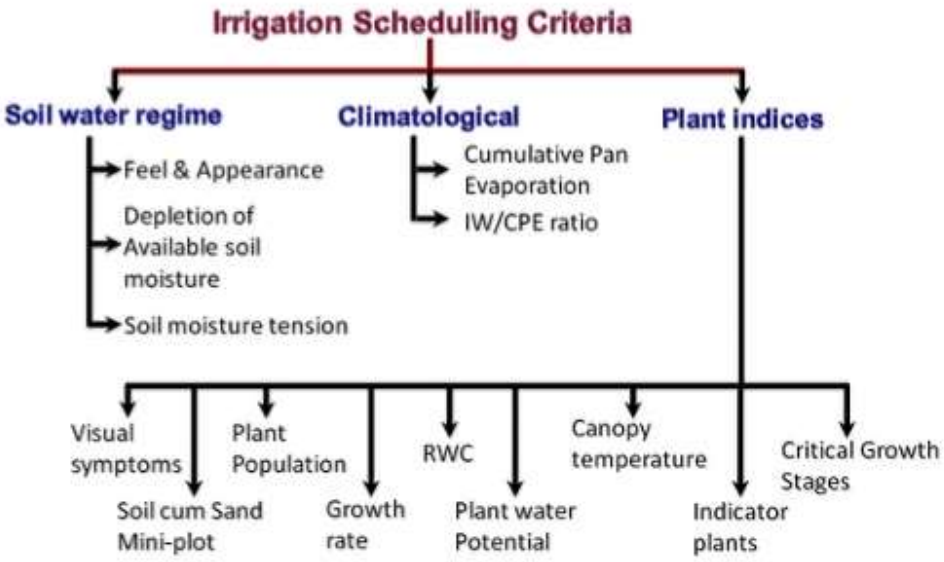


Fig 3.6 Irrigation Scheduling Criteria[4]

3.3 Manures, Fertilizers and Nutrients Management

Manures are the plant and animal waste. They are used as a source of plant nutrients after their decomposition which can be grouped into bulky organic manure and concentrated organic manure. The former are in the main used as manure, compost from organic waste, night soil large image or green manures, while the latter comes from the edible or non-edible oil cakes or bone meal.

[4] Source : https://agristudent.com/how-to-do-irrigation-scheduling-for-crops-agristudent-com/

Fertilizers include industrial manufacturing chemicals that contain plant nutrients. There are more nutrients in fertilizers than organic minerals and nutrients. There are three groups of fertilizers:

- straight fertilizers which supply single nutrients such as murate of potash,
- complex fertilizers supplying two or more nutrients such as NPK Complex, and
- mixed fertilizers that supply two or more nutrients such as groundnut mixture.

Fertilizers and manures have multiple roles in crop production such as:

- they bind the sandy soil and improve water holding capacity which opens the clay soil,
- they help in aeration which means a better root growth,
- organic manure helps plant nutrients to add in the soil in a small percentage which adds micronutrients which are essential for the growth of plants,
- manures increase the microbial activities in the soil,
- fertilizers supply essential nutrients to the crops which are manufactured in forms that are ready to use by plants directly and there is a rapid transformation in them.

The dose of fertilizer can be adjusted after the testing of soil that can provide a balanced application of nutrients which is required for the crop.

Integrated Nutrient Management

In this concept there is a judicious combination of inorganic or organic and biofertilizers required as a soil nutrient. The concept of INM includes the nutrient sources, method of irrigation, method of organic and inorganic matter, and application to maintain soil fertility and productivity of crops. Complimentary use of chemical fertilizers, organic chemicals or organic fertilizers and biofertilizers is done to ensure the nutrient supply. A thorough understanding of the effect of the previous crop is required. The contribution of legume in the cropping system is a dual effect of fertilizers and residual and cumulative effect of organic manure for supplementing and implementing the use of fertilizers and chemicals. The balanced fertilization in the case of integrated nutrient management means it doesn't require the proportion of nitrogen, phosphorus, and potassium but it should be taken into account the availability of nutrients which is already available in the soil crops requirement. Along with the same, other factors such as the removal of nutrients, economy of fertilizers and ability of the farmer to invest through techniques of soil moisturizing, weed control, seed rate, sowing time and many more aspects have also to be considered. Therefore, this is a dynamic concept where the balanced use of fertilizers should be having certain purposes such as the correction of inherent soil nutrient deficiency, increased crops quality, increased farm income, maintenance of lasting soil fertility, avoiding damage to environment, and restoration of productivity of land.

To put balanced nutrition into the soil, one of the important tools is soil testing. In the case of balanced fertilizer rate, the difference from area to area as well as a crop to crop through soil testing will help farmers to know how much and what kind of fertilizers are required for each crop.

Fertilizer Use Efficiency

Various economic measures are used to increase the fertilizer use efficiency such as the best fertilizer sources using balanced fertilizer, using adequate research and diagnostic techniques, integrated nutrient management as well as utilization of residual nutrients. Best fertilizer resources are one of the fundamental requirements of better crop production where the source of fertilizer depends on the crop as well as the variation of climatic and soil conditions, etc.

There are various forms of fertilizers such as:

- for nitrogen in the form of nitrate,
- for Phosphorus water-soluble or insoluble Phosphorus is required,
- for Potassium Murate of Potash is required,
- for Sulphur, sulfate for elemental sulfur is required,
- for multi-nutrients there are MAP, DAP, SSP and Nitrophophates, and
- there are various combinations of NPK, while in the case of four or five fertilizers such as neem coated urea, zincate urea, carbonated SSP, NPKS mixture, etc., for increase of multimixer.

It is important to use an adequate rate of a recommended fertilizers with the diagnostic techniques so that it can meet the demand of crops at any point of growth. There are several diagnosing methods such as:

- The state recommended generalized fertilizer doses,
- chlorophyll meter,
- leaf color chart,
- soil test based on fertilizer recommendations,
- soil test crop response-based recommendations, and
- plant analysis for diagnosis and nutrient deficiencies.

This is important to apply a balanced fertilizer requirement that includes an adequate supply of all the essential elements with the proper method of application at the right time as well as nutrient interrelationships.

Classification of Organic Manures

They are divided into bulky organic manure and concentrated organic manure.

- Bulky organic manures include farmyard manure, compost, sewage and sludge.
- Concentrated organic manures include oil cake and waste of slaughterhouses.

Green manures include leguminous plants and non-leguminous plants, while green leaf manures cover trees like neem, Gliricidia, etc.

- Farmyard manure is produced on the farm made up of excreta such as cow urine of farm animals, bedding material provided for them, and various forms of household waste. Farmyard manure is not a standardized product and its value depends on the kind of feed to the animals and the amount of straw used in storage. There is a considerable variation due to bacterial activities and a rise in temperature in manure.
- Compost is derived from the decomposed plant residue made by fermentation of waste plant material which gives output into a pit usually in a larger area which brings the plant nutrients in a more readily available form.
- In cities the human excreta are flushed out with large quantities of water called the sludge. It includes two components, one is the solid portion and another liquid which is called sewage water.
- Concentrated organic manures have a higher nutrient content than bulky organic manure. Important concentrated organic manures are oilcakes, blood and bone meal, fish manure and pressmud, etc. They are also known as organic nitrogen fertilizers.
- Oil cakes, the coarse residue obtained after the oil is removed from oilseeds, are rich in protein and minerals and valuable as poultry and other animal feed. They may be broken up and sold or grounded into oil meal. Content of nitrogen varies between 3% and 9%. CN ratio is usually 32:15 for most of the oil cakes.

- Green manure is a cover crop sown on an agricultural plot to fertilize the soil. It provides an improvement in soil structure with its root system and a relatively little supply of stable organic matter. It acts as a boon for roots, preferably grown in situ and incorporated into the soil, while the green leaf manures are the incorporation of green manure into the soil and transported from elsewhere.
- Stem nodulating green manure includes leguminous green manure plants that produce root nodules and fix atmospheric nitrogen such as Sesbania rostrata that produce nodules on their stem beside root nodulation. Almost 22 tons of fresh biomass could accumulate 150 kg nitrogen per hectare and 45 days which contains 3.3 % nitrogen. Green manure adds acid in the reclamation process besides improving the fertility status of the soil. Daincha crop helps in the reclamation of saline and alkaline soils. Placing sodium on the exchange complex with a more favourable cation is helpful for the reclamation of alkali soil. Replacing exchangeable sodium is the consequence of the improvement of alkali soil.

Classification of Fertilisers

A fertilizer is any material of natural or synthetic origin that is applied to soil or plant tissues to supply one or more plant nutrients essential for the growth of plants. Many sources of fertilizer exist, both natural and industrially produced. Fertilizers enhance the growth of plants. This goal is met in two ways, the traditional one being additives that provide nutrients. The second mode by which some fertilizers act is to enhance the effectiveness of the soil by modifying its water retention and aeration.

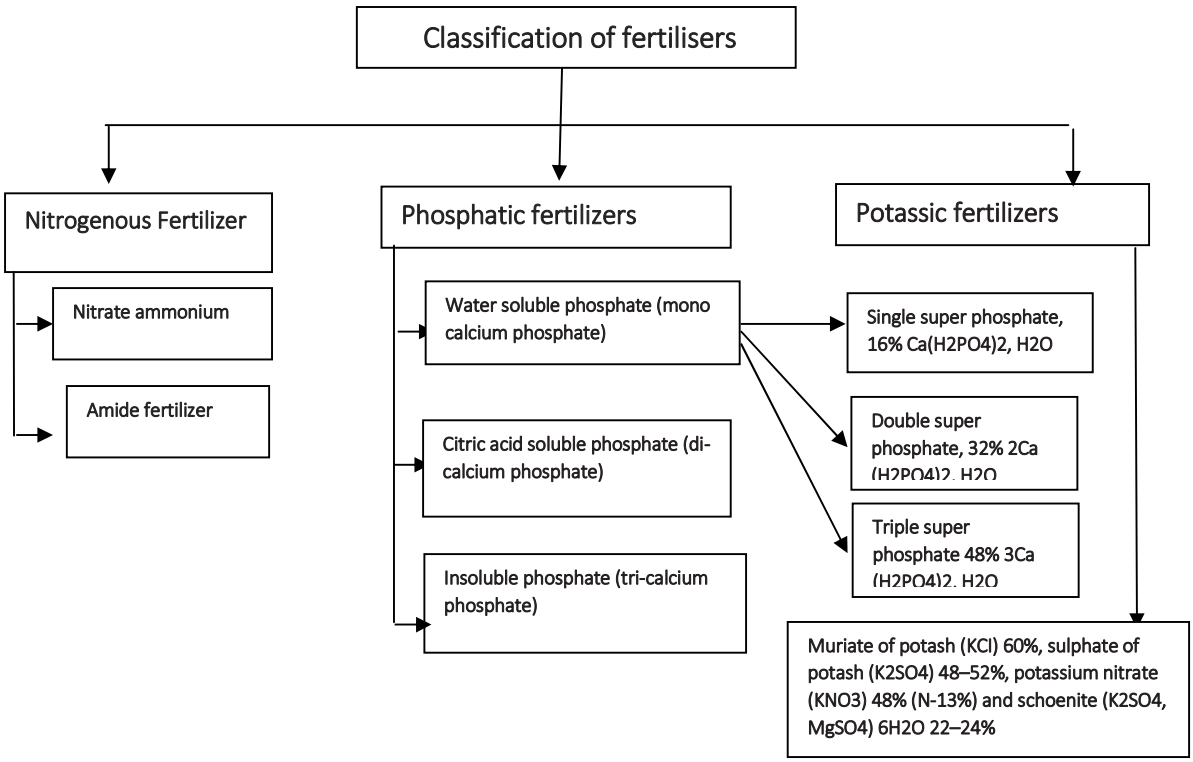


Fig. 3.7 Classification of fertilizers

- Straight fertilizers are utilized for providing only one primary plant nutrient either N or P or K. On this basis, the can be straight nitrogenous, straight phosphatic, or straight potash fertilizers. For example, urea provides only N, while potassium chloride provides only K.
- Phosphatic manures are the composts characterized into three groups on the dissolvability of phosphate in the manure. The classification is:
    - water-soluble phosphate, i.e., monocalcium phosphate,
    - citric acid-soluble phosphate, i.e., dicalcium phosphate, and
    - insoluble phosphate, i.e., tricalcium phosphate.

Water-soluble phosphates are

- single super phosphate,
- double superphosphate, and
- triple superphosphate

While citric acid-soluble phosphate is the basic slag, raw or steamed bone meal. Citric acid-insoluble phosphate is rock phosphate, raw bone meal and steamed bone meal.

- Potassic fertilizers are divided into various types such as murate of potash, sulfate of potash and potassium nitrate.
- There are compound fertilizers that are commercial fertilizers in which there are two or more primary nutrients chemically combined which contain 18% nitrogen and 46% phosphorus. Examples of compound fertilizers are diammonium phosphate, mono ammonium phosphate, urea ammonium phosphate and ammonium phosphate.
- Complex fertilizers are commercial fertilizers that contain at least two or more primary essential nutrients with a higher concentration of the compound. The nutrients are physically mixed and they include nitrogen, phosphorus and potash. There are other examples of nitro phosphate potash and gromor.
- There are some other categories of fertilizers called mixed fertilizers which are a mixture of two or more straight fertilizers. In certain cases, the complex fertilizer can also be used as one of the ingredients. The mixing of fertilizer is done mechanically so that every grain can contain all the nutrients mixed in the mixture.
- There are salt-containing secondary nutrients as well as salt containing micronutrients. The former are calcium sulphur and magnesium because they are required less in quantity than primary nutrients but more than micronutrients which are to some fertilizers like ammonium sulphate, calcium ammonium nitrate and phosphate fertilizers. Various commercial fertilizers contain secondary nutrients such as magnesium sulphate which contains 9.6% mg. and 13% is and Calcium sulphate that is gypsum which contains 9% calcium and 23% sulphur. Salt-containing micronutrients such as copper, zinc, boron, magnesium, molybdenum, iron and chlorine are required in micro quantities which are added to the soil through some commercial fertilizers such as copper sulphate, zinc sulphate, borax, magnesium sulphate, sodium molybdate, ammonium molybdate and ferrous sulphate.

Biofertilizers

Biofertilizers contain microbes which help in promoting the growth of plants and trees by increasing the supply of essential nutrients to them. They comprise of living organisms which include mycorrhizal fungi, blue-green algae and bacteria. Mycorrhizal fungi preferentially withdraw minerals from organic matter for the plant whereas cyanobacteria are characterized by the property of nitrogen fixation. The latter is defined as the process of converting the di-nitrogen molecules into nitrogen compounds. For instance,

some bacteria convert insoluble forms of soil phosphorus into soluble forms. As a result, phosphorus is available for plants.

Rhizobium is a genus of bacteria associated with the formation of root nodules on plants. These bacteria live in symbiosis with legumes. They take in nitrogen from the atmosphere and pass it on to the plant, allowing it to grow in soil low in nitrogen. There are various types of the family of Rhizobium and it requires certain host plants, for example, microbes that live harmoniously with soybean cannot live with alfalfa. There is a certain classification of Rhizobium leguminosarum association such as Rhizobium meliloti which can live on alfalfa while Rhizobium trifolii on clover, Rhizobium leguminosarum on peas.

Table 3.5 Classification of Rhizobium–Legume Associations

Rhizobium species	**Legumes**
Rhizobium meliloti	Alfalfa (Lucerne)
R. trifolii	Clover
R. leguminosarum	Peas
R. phaseoli	Beans
R. lupine	Lupine
R. japonicum	Soybean
Rhizobium sp.	Cowpea

- Legumes can form a symbiotic relationship with nitrogen-fixing soil bacteria called rhizobia. The result of this symbiosis is to form nodules on the plant root within which the bacteria can convert atmospheric nitrogen into ammonia that can be used by the plant.
- Azolla is a unique freshwater fern that is one of the fastest-growing plants due to its symbiotic relationship with a cyanobacterium ('blue-green alga') called Anabaena. It is a floating pteridophyte that is used as a biofertilizer in the rice fields. It is incorporated into the soil before the rice plantation or planted as a dual plantation along with the rice plants. Azolla–Anabaena can fix almost three times more atmospheric nitrogen than legumes. Typical rates for legumes are 400 kg. of nitrogen per hectare per year. Those for Azolla-Anabaena are 1100 kg. of nitrogen per hectare per year. At present several Azolla species are under cultivation in India, e.g., Azolla filiculoides and Azolla rubra in cold areas of India, while A. Mexicana, A. microphylla, A. nilotica, and A. pinnata grow under tropical conditions as they are tolerant to high temperature.
- Azospirillum is known for its nitrogen-fixing and phytohormone production ability. It is one of well-studied plant growth-promoting rhizobacteria from lab to field. None of its species or strains is a human or plant pathogen. It is considered as the safest bacteria that can be used as a biofertilizer at the commercial level for several crops, especially cereals and grasses including wheat and rice. Some of its species are reported for phosphate-solubilizing ability and high salt tolerance. Azospirillum is recommended for rice millets, maize, wheat sorghum, etc., and it fixes 20-40 kg. N/hectare.
- Azotobacter- These are the microbes that are aerobic and free-living in soil, which has an important contribution to the nitrogen cycle. Azotobacter works with the atmospheric nitrogen and converts in the form of ammonium ions and released into the soil. This is the nitrogen

fixation of the inaccessible form of atmospheric nitrogen. There are some biologically active substances consist phytohormones, which stimulated plant growth such as auxins, are synthesized by Azotobacter. Azotobacter helps in the bioremediation of soil from heavy metals like cadmium, mercury, and lead. Azotobacter can biodegrade 2,4,6-trichlorophenol, which is chlorine contained aromatic compound. 2, 4, 6-triclorophenol used as insecticide, herbicide, and fungicide but some mutagenic and carcinogenic effects were also found.

- Blue-green algae are photoautotrophic and prokaryotic algae. They are free-living creatures and are also known as Cyanobacteria. They fix the atmospheric nitrogen in moist soils. BlueGreen Algae (BGA) find a favorable abode in the waterlogged conditions of rice fields and provide cheap nitrogen to plants, besides increasing crop yield by making the soil vital, fertile and productive. BGA biofertilizer in rice, popularly known as “Algalization”, helps in creating an environmentally safe agro-ecosystem that ensures economic viability in paddy cultivation while saving energy-intensive inputs.
- Mycorrhiza is another function that is used as a biofertilizer. It is called vesicular Arbiscular mycorrhiza. Arbuscular Mycorrhizal Fungi (AMF) constitute a group of root obligate biotrophs that exchange mutual benefits with about 80% plants. They are considered natural biofertilizers since they provide the host with water, nutrients and pathogen protection in exchange for photosynthetic products.

Methods of Fertilizer Application

The proper method of application of fertilization is important as fertilizers needs are different with different types of methods of application.

- Nitrogen and potash are required to apply as a broadcasting and bund placement.
- Water-soluble phosphorus fertilizer is required to apply as a bund placement in neutral and alkaline soil.
- Citrate soluble phosphorus fertilizer is applied in a broadcast method in acidic soil.
- Bisulfate forms of sulphate fertilizer are required to apply in broadcasting or band placement.
- Sulphur element is required to apply in broadcasting method.
- Certain micronutrients can be applied in small quantities as a foliar spray.
- Water-soluble fertilizers are applied with the help of fertigation.

The time of application of fertilizers also depends on the physiology of the crop. There are different types of applications of fertilizers for various crops like plain crops are applied 2 splits of fertilizers at the seeding stage and 3-5 weeks after the first dose, while in the case of flooded rice, 3 splits are important at the transplanting stage when there is a 3 and 6 week after the first dose. Considering nutrient interrelationship is important because there is certain antagonistic nature of fertilizers. Some of the fertilizer applications in excess can cause the loss of yield and quality of crops.

There are a number of essential elements required for the crop growth which are broadly classified into five categories. They are based on the relative quantity that is normally present in the plant, chemical nature, general function and mobility. Based on the relative quantity which is normally present in the plants, it is divided into three categories, viz., macronutrients, secondary nutrients and micronutrients.

- Macronutrients are the major nutrients or primary nutrients such as carbon, hydrogen, oxygen, nitrogen, phosphorus and potassium.

- Secondary nutrients are calcium, magnesium and sulphur, while micronutrients are iron, magnesium, zinc, copper, molybdenum, boron, sodium and Iodine.

The classification is based on their chemical nature and has been divided into four categories of metals, non-metals, cations and anions.

- Metals: K, Ca, Mg, Fe, Zn, Mn, Cu, Co, and V, etc.
- Non-metals: C, H, O, N, P, S, B, Mo, C1, Si, etc.
- Cations: NH4 +K+, Ca2+, Fe2+, Mg2+, Mn2+, Cu2+, Zn2+
- Anions: NO3−, HPO42−, H2PO4−, SO42−, BO33−, MoO42−, C1− etc.

Choice of the method as well as the time of application depends on the form as well as the number of fertilizers, convenience of the farmers, and efficiency and safety of fertilizer application. Fertilizers are of various forms such as solid and liquid. In the case of solid form, some methods are more established like broadcasting, while for the liquid form the common application methods include fertigation.

- In the case of the solid form of fertilizers, broadcasting is one of the important methods where manure and fertilizers are scattered uniformly in the field before planting the crop and it can be incorporated by tilling or cultivation practices.
- In the case of drilling and placement, fertilizers can be placed in the soil. It can be done by plough sole placement, deep placement and subsoil application.
- In plough sole placement method the fertilizer is applied or dropped in the plough sole which is covered by the plough during the opening of the adjacent furrow. In deep placement method the fertilizer and manure are placed at the bottom of the topsoil at a depth of 10 to 12 cm., especially in the puddle rice soil. In subsoil application the fertilizers are applied to it, especially for three crops or in the case of orchard plants at a depth above 15 cm.
- In case of location or spot application, the fertilizers are placed in the root zones or the spot which is near the roots. From the roots, fertilizers can be absorbed easily. It can be done by five methods, i.e.,
    - contact of drill placement,
    - band placement,
    - pocket placement,
    - side dressing and
    - pellet application.

In the case of liquid fertilizer, application on the foliage of the plant for quick recovery from the deficiency is done either from the nitrogen or the sulphur deficiency. There are three methods for the apploation of liquid fertilizer:

- Fertigation, that is, the fertilizer is dissolved in the irrigation water either in the open or closed system and it is sprinkled or trickled.
- Another method is starter solution where the solutions of a fertilizer prepared in low concentration are used for soaking seeds.
- Liquid fertilizers can be applied directly to the soil with special injecting equipment as liquid manure, urine, sewage water and cattle shed washings are directly let into the field.

To Do Activity

1. What are the bio-fertilisers and micro-organisms which are applied in the crops of your region?
2. Discuss the effective methods of fertiliser application.
3. Discuss the use of organic manures/compost over the fertilisers.

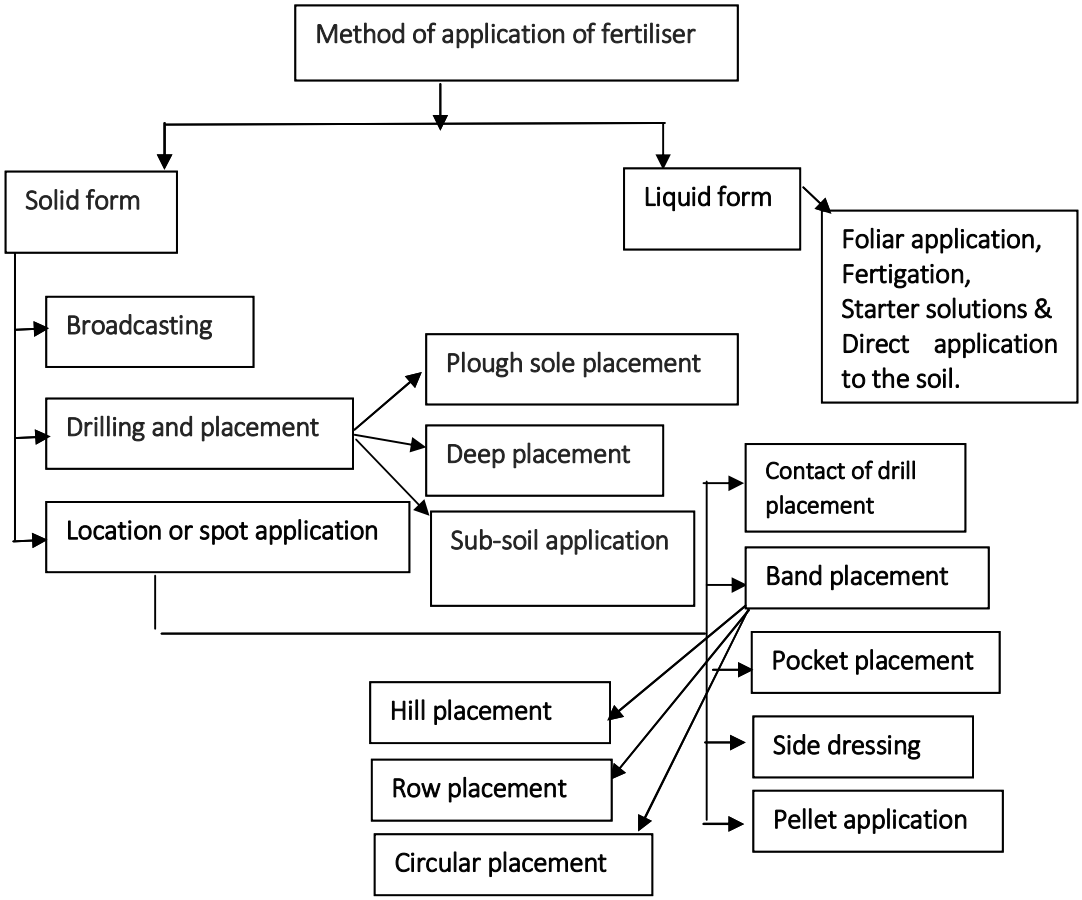


Fig. 3.8 Method of application of fertilizers

3.4 Weed Management

Weeds are plants which grow where they are not wanted. A weed reduces the use of crop quality by competing with the crop for water. When toxins are produced, it hosts insects, diseases and nematodes which attack the crop. Sometimes weed interfere in other operations such as harvesting operations and at that time contamination with wheat seeds or other plant parts makes it unfit for the market. So the profitability and crop production depend on an effective weed control.

Development Stages of a Weed

It has four stages of development, viz., seedling, vegetative, reproduction and maturity. In the seedling stage, it is a small and delicate newly emerging plant, while in the vegetative stage it grows quickly from the roots and leaves. In the case of seed production, plant energy consumes directly into the production of flower and seeds, while at the maturity stage it produces a little or no energy and a plant begins to dry out or desiccate.

Weeds are the unwanted plants and various definitions are given by various people. According to the Oxford English Dictionary, it has been defined as a herbaceous plant not valued for use or growing wild and hindering the growth of superior vegetation. There are many more definitions of weeds given by plants scientists, ecologists and amateurs. Overall, a weed is a plant which originates in natural environment and interferes with our crops and activities.

Regarding the characteristics of weeds, they are competitive, adaptable and they grow in adverse situations also. Their reproductive mechanism is superior to that of crop plants, particularly under favourable conditions. Thus weeds constantly try to succeed over leftover it crop plants.

There are certain harmful effects of a weed such as:

- It can compete with the place for space, light and motion effect. Besides, it affects the quality of the farm produce and livestock products like milk and skin.
- Weeds can promote pests and diseases that can cause health problems to the human beings and have effects on fishing, swimming and recreation.
- Some weeds are poisonous for the livestock.
- Weed reduces production of crops and its quality as well as act as a reservoir of pests and diseases.
- It can interfere with crop handling as well as reduce the land value.

However, there are beneficial effects of weeds such as:

- They can be used as fodder.
- They are used as green vegetables like amaranthus.
- In some cases they work as a soil binder.
- They act as manure and a source of fuel.
- Certain weeds have medicinal values.

Table 3.6 Medical value of weed plants

Weeds	**Medicinal values**
Phyllanthus niruri	Jaundice
Eclipta alba	Scorpion sting
Centella asiatica	Improves memory
Cynodon dactylon	Asthma and piles
Cyperus rotundus	Stimulates milk secretion
Leucas aspera	Snakebite
Calotropis procera	Gastric trouble
Abutilon indicum	Piles

Classification of Weeds

Classification of weeds is based on morphology, life span, ecological affinities, soil type, botanical family, etc. There are other classifications of weeds based on phylogenetic relationship, plant life span, ecological affinities, soil type, place of occurrence, soil pH, morphology, nature of stem and specificity. Classification is also based on their economic importance as well as according to the association.

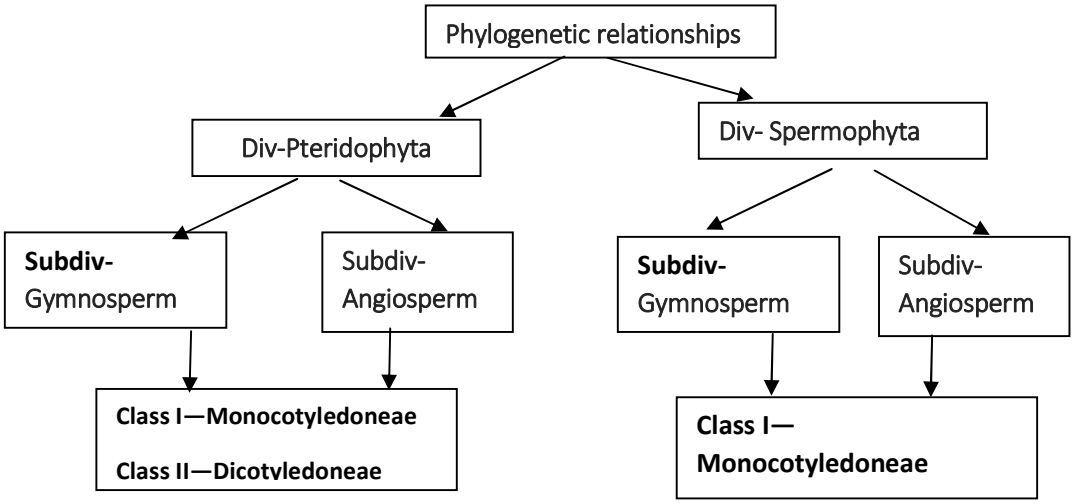


Fig. 3.9 Phylogenetic basis of weed classification

- Based on phylogenetic relationships, plant species can be based on ancestral similarities which include division, subdivision, class, family, genus and species.They can be divided into two divisions: Pteridophyta and Spermatophyta, and there are two subdivisions, that is, Gymnosperm and Angiosperm in which there are two classes, viz., monocotyledon and dicotyledon.
- On the basis of the life span, they are annual, biennial and perennial weeds. Annual weeds live only for a year. They have a shallow root and weak stems which produce seeds in profusion and the mode of propagation is basically through seeds. Common weeds are monsoon annual and winter annual. In the case of biennial weeds, complete vegetative growth is in the first season, while flower and seeds in the succeeding years and then they die. They are found in the non-cropped areas. Perennial weeds live for more than two years and may even alive almost indefinitely. They not only propagate through seeds but also from underground stems, roots, rhizomes, etc., That is why they are further classified into the simple perennial, bulbous perennial, corm perennials and creeping perennials.
- Based on ecological affinities, weeds can be divided into wetland weeds, garden land weeds, and irrigated land and dry land weeds. Wetland weeds are tender annuals with semi-aquatic habitats which can survive under waterlogged and partially dry conditions. They propagate chiefly by seeds. Garden land weeds neither require a large quantity of water like wetland weeds nor a drought as a dry land weed. Dryland weeds require hardy plants with a deep-rooted system.
- Based on soil type, weeds can be divided into those of black cotton soil, red soil, light sandy loam soil, and laterite soils.
- Based on the place of occurrence, weeds can be divided into those of crop plants which infest the cultivated land and cause hindrance to the farmers for successful crop production. Besides, there are weeds growing on pasture lands, waste lands, playgrounds, roadside, etc.
- Based on their origin, weeds can be divided into indigenous as well as exotic weeds.
- Based on the cotyledon number, they can be divided into dicot and monocots.
- Based on soil pH, weeds can be classified into three categories, i.e., acidophile, basophile and neutrophil.
- On the basis of the nature of stem, they can be divided into woody, semi-woody and herbaceous weeds. It is the basis of the development of bark tissue on their stems and branches which is considered.
- Based on specificity, weeds are poisonous, parasitic and aquatic weeds.
    - Poisonous weeds cause ailments for livestock animals which may cause death. They are harvested along with the fodder and provided to the animals as feed.
    - The parasitic weeds are totally or partially dependent on the host plants. They are based on the parts of the plants and divided into total root, partial root, total stem and partial stem parasite weeds.
    - Aquatic weeds develop in water and are of four classes, i.e., submersed, emersed, negligible and gliding weeds. Submersed weeds are vascular plants that produce most of the vegetative development underneath the water surface and having roots, stem, and leaves. Emersed weeds are established in the base mud, while the flying stem and leaves are not in the water surface which is a wide and numerous plants and now and again like grasses. Minimal weeds can develop in sodden shoreline zones with the profundity of 60-90 cm water. The weeds are diverse in size, shape, and propensity and it comes in the significant genera of this gathering, eg. Typha, Polygonum. The

skimming weed drift on water surface either separately or in bunches which are free gliding and some established in mud base.

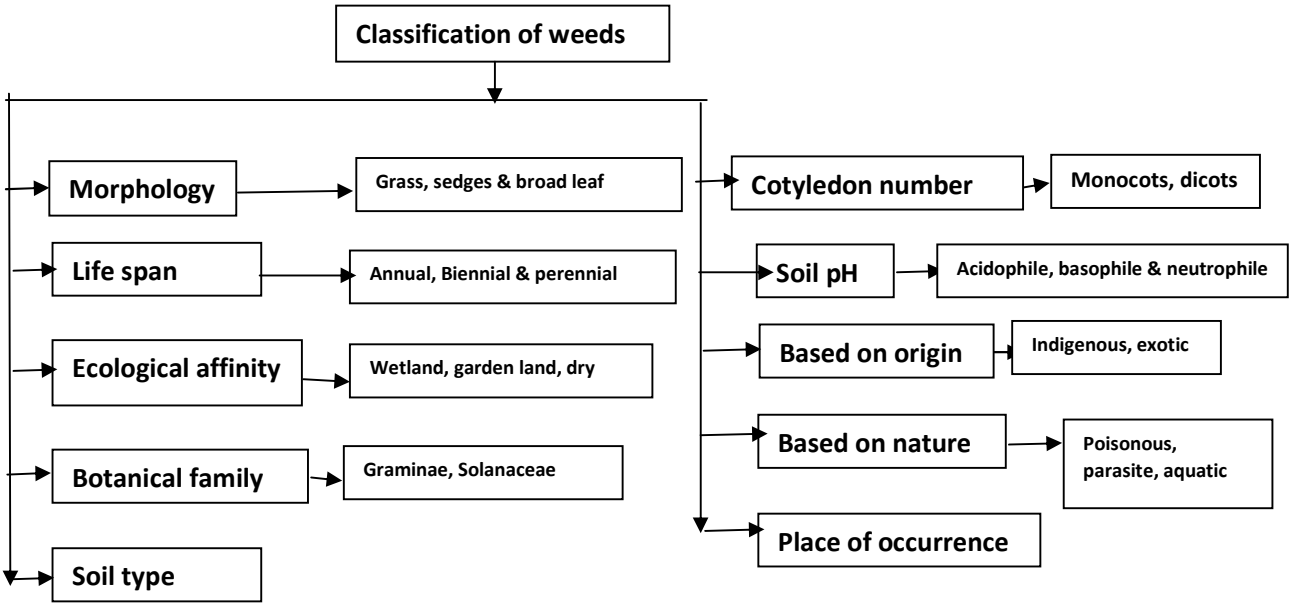


Fig 3.10 Classification of weeds

- Based on association, the weeds present in the crop fields are different from the soil and climatic requirements, cultural requirements, seed size, and food habits. There is a close association with climate and crop that can be in a season and with a crop that also can be classified into three groups. These are season bound , crop bound and parasitic weeds. Season bound weeds are according to the calendar year: monsoon, winter, and summer.
- Crop bound weeds or parasitic weeds are the plants that attack other plants by making connections and deriving part or all of their food from the host. They attach themselves either to the roots or the shoots of the host plants and survive on food material available in them. That can be divided into three groups i.e. total parasitic weeds, semi-parasitic weeds and non-parasitic weeds.
- Crop-associated weeds associate with a particular crop for any of the causes like the need for specific microclimate, mimicry or contamination of crop seeds. If there is a need for a specific microclimate, they can grow best in that condition and along with that particular association weeds are associated with a particular crop. Mimicry means resemblance of a particular crop, mimicry in plants where a weed comes to share one or more characteristics with a domesticated plant through generations of artificial selection. In the case of contamination of crops weeds like Oryza sativa in rice and Phalaris minor in whea, they can be mixed with the other crops because they have the same height as well as other features of the crop. Therefore, because of the morphological similarity with associated seeds, they can be contaminated and can be grown.

Weed Control

There are various mechanisms for weed control, such as cultural, mechanical and chemical methods.

- Cultural weed control includes non-chemical crop management practices ranging from a variety selection from land preparation to harvesting and post-harvest processing. Several cultural practices like tillage, planting, fertilizer application and irrigation are employed for

creating favorable conditions for the crop. These practices if used properly help in controlling weeds. Cultural methods alone cannot control weeds but help in reducing the weed population.

- In the case of mechanical control, the weeds seeds in underground plant parts are destroyed, whereas small and minute weeds are more effectively controlled with tillage practices in which the soil is disturbed. However, it can bring new weed seeds which creates more problems.
- The first step of successful chemical weed control is the correct identification of the weeds so that selective herbicides can be used to control the weed with little or no injury to the crop. The time and rate of herbicide application are important. If applied at the wrong time, often the result is an insufficient control and crop injury.

Integrated Weed Management

It may be defined as the combination of two or more weed control methods at low input levels to reduce weed competition in a given cropping system below the economical threshold level. It allows producers to design their weed management programme around what is more effective for a particular weed, crop and farm operation. There are mainly five components in it, viz., prevention, mechanical, cultural, biological and chemical.

- Monitoring of inputs in the farm to avoid contamination with weed seeds. Such areas may local, regional or national can be done for prevention. Weed control measures may not be successful until adequate preventive measures are taken to reduce the infestation. Measures like separating crop seeds from the mixture of crop and weed seeds by using physical difference methods like size, shape, colour, etc., can be taken.
- In mechanical method, there are mechanical tools to restrict the growth and survival of weeds which include for burning, etc. Other technologies are at harvest time the destruction of cover crops, rollers and robotic weeders which need to be integrated when appropriate in a larger integrated weed management programme.
- In the cultural component, there are some common examples which include row spacing, crop rotation, crop varieties, timing of plantation and cover crops, nutrient management, etc.
- Biological components of integrated weed management include the use of living organisms such as livestock Inspector nematodes, fungi and bacteria to target the weeds. With the biological agent, specific weed species are attacked.
- In the chemical component of integrated weed management, herbicides are a key part which is conventional in some organic systems. Suitable modes of action are essential for an effective control of resistant weeds.

Types of Herbicides

Chemical weed control can be done with the application of herbicides at

- preplant incorporation,
- pre-emergence, or
- post-emergence stage.

There are certain advantages of pre plant-soil application of herbicides as early weed control can reduce weed competition with a crop. In case of that, it will not delay cultivation, and herbicide application can control the weed crop. Pre-plant soil application and incorporation are less dependent on rainfall for herbicide activation than pre-emergence herbicide application. Herbicides in this group must be mixed

into the surface soil before planting to achieve good weed control. Usually, herbicides that must be incorporated into the soil are highly volatile. Without incorporation, they are lost in the air as a gas.

A pre-emergence herbicide is usually applied immediately after planting. Pre-emergence means that the herbicide is applied after the crop seeds are planted but before the crop and weeds have emerged from the soil. This group of herbicides usually needs rain within a few days after application to move the herbicide from the soil surface down into the top layer of the soil where most weed seeds are located. Advantages related to the pre-emergence applications are that early control of weeds can reduce the weed's competition with the crop. It can be used in a tillage system as well as plantation and herbicide application may be done at the same time. Its disadvantage is that it depends on the rainfall and is ineffective in dry soil conditions. In the case of sandy soil, the heavy rain may affect the movement of the herbicide down in the soil to the germination of crop seeds which can cause injury to the crop.

Post-emergence herbicides are applied after the weeds and crops have emerged from the soil. These treatments can be applied in either a broadcast or directed fashion. When applying post-emergence herbicides, it is necessary to have maximum coverage of the weeds with the spray solution. Surfactants are often used with post-emergence herbicides to enhance control. They are of two types, contact and systemic herbicides.

- Contact herbicides can kill the plant parts whicht touch and that are typically above-ground part of a weed such as the leaves and stems which can turn brown and die. It can be commonly used to control annuals, e.g., paraquat.
- Systemic or translocated herbicides are absorbed by the weed roots and leaves. They move throughout the plant system. They are more effective than the contact herbicides against perennial weeds because they reach all parts of the plant and it can translocate herbicide which might take two to three weeks to kill the weeds eg. Glyphosate. Advantages of the post-emergent applications are that herbicides can be applied after the weed emerges. Herbicide application can be useful for the spot treatment as well as the post-emergence herbicide application, and has short or no soil residual effect.

Herbicide Additives or Adjuvants

Herbicide additives are added in herbicide to increase its effectiveness. Herbicide formulation includes its own particular set of adjuvants to optimize the performance mixing and handling of the active ingredients. They are used primarily in the case of post-emergence herbicide application to improve the coverage of leaf surface and area so that it can penetrate the leaf. It does not increase the effectiveness of soil-applied herbicides. Herbicide compatibility problem usually occurs when applicators do not follow mixing directions.

To Do Activity

- Discuss in a group the types of weeds found in cereal crops and measures to control them.
- Debate on the chemical and preventive measures of weed control in the case of monocotyledons.

3.5 Growth Analysis and Plant Protection

Plant Protection Methods

This is an important aspect to increase the productivity from the farm. A farmer has to minimize the crop losses which demand proper sustainable agricultural practices. For improvement of productivity of crops, he needs to have a good crop variety, production management and protection management. Crop protection is the method to increase the crop yield protecting it from pests, diseases, weeds and other organisms that damage it. Growth analysis and plant protection include management of weeds, pests, insects and plant diseases.

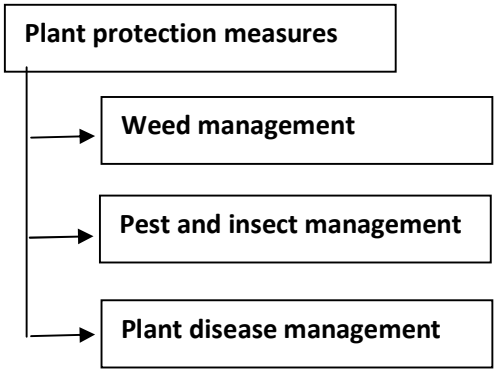


Fig. 3.11 Plant protection measure

The pests of crops are mainly external and their accompanying species such as predators, parasites, pollinators, competitors and decomposers perform a wide range of ecosystem functions.

Integrated Pest Management (IPM)

It is a technique of defense against the pests and diseases in agriculture to maintain a healthy ecosystem, where the productivity of crops and sustainability can be increased. Some environmental factors are useful in pest management like:

- soil management,
- water stress,
- crop varietal resistance,
- timing and spatial arrangements.

Soil management can apply an ecosystem approach such as mulching, building soil organic matter and addressing soil problems (such as salty water incursion) which render crops less susceptible to pests like rice stem borers. In water stress, there is the possibility to increases the susceptibility of crops to diseases. Some pests such as weeds in rice can be controlled by the management of water in the production process.

Crop varietal resistance also helps to manage plant diseases and insects where vulnerability can arise if the genetic base of resistance of the host plant is not broadening.

IPM is a pest management technique is associated with the environment and population dynamics along with the utilization of appropriate techniques to minimize the pest population at the level below those causing economic injury. It includes cultural methods, biopesticides, botanicals, behavioral methods as well as biological methods.

Cultural Methods

They are agronomic adjustments required for a better return and simultaneously it coordinates avoidance, mass duplication and spread of vermin by adjustment of the harvest microclimate. This incorporates sterilization, culturing, development choice, season of planting, plant population, excrements and manures, and irrigation.

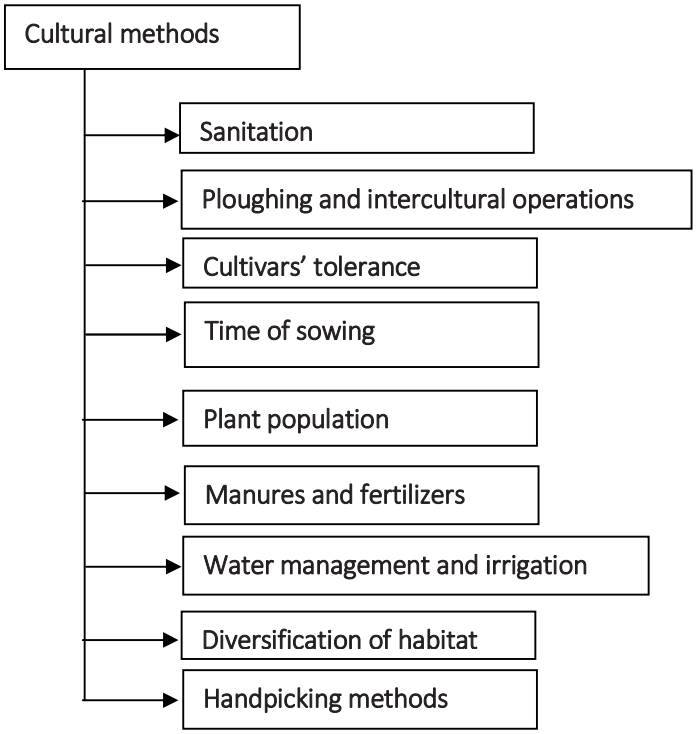


Fig. 3.12 Types of cultural methods of crop protection

- **Sanitation** includes removal of breeding refuges and overwintering of pests. Destruction of alternate hosts minimizes pest population growth.
- **Ploughing and intercultural operations** bring favourable conditions for the multiplication of pests as well as diseases along with growth of weeds. Therefore, in the pupae stage it could get exposed to dehydration or to predate the birds which could also mechanically damage or be buried deep into the soil.
- **Cultivars' tolerance** to pests and diseases can be developed according to the suitability of agro-climatic conditions and their selection can bring down losses in crop productivity.
- **The time of sowing** can be an important condition to influence the pest and disease attack. For instance, rice may suffer less from borer attack if planted early June. Similarly, maturing cotton cultivars have become popular in Punjab and Haryana to escape the pink bollworm.
- **Plant population** per unit area can influence the crops microclimate in the long term such as a dense crop canopy can lead to high humidity which is more conducive for the attack of insects, pests and diseases.
- **Manures and fertilizers** application can also deter the attacks of insect pests as well as diseases. If excessive nitrogen is there, it increases the susceptibility of crops to sucking and leaf-eating insect pests.

- **Water management and irrigation** functions affect the pest attack. Irrigation can reduce the soil-inhabiting pests by suffocation or exposing them toward soil surface, which can be preyed by birds. Diseases such as anthracnose of the beans, early blight and charcoal rot of potato can be checked more by furrow irrigation than sprinkler irrigation.
- **Diversifications of habitat can** also impact the infestation chances as many pests prefer to feed on particular crops. By crop rotation, intercropping, trap crops and strip cropping, the probability of pests can be brought down.
- **Handpicking methods** is useful if the cropping is in a small area. A small quantity of kerosene can poured into a polythene bag and pick up the larvae in the evening. Apart from the handpicking of insects, wild grasses and weeds can be removed from the field bunds so they will not have suitable places to lay the egg.

Bio-pesticides and Botanicals

Bio-pesticides: Microorganisms are used for pest control which includes the artificial media culture as well as inoculum at the field. Various fungi and bacteria can handle this but insect viruses can arise on living insects. Biocontrol agents are used on the targeted insects and pests which are similar to the chemical pesticides. Therefore, they also called bio-pesticides or natural pesticides. Among the examples, Bacillus thuringensis is a bacterial pathogen that infests a number of insect pests. It is used against the caterpillar attack for a wide range of crops. There is a commercial formula for the bacteria such as Dipel, Delfin, Halt, Spicturin, Biolep and BioAsp. Bacillus popilaleisis used against the white grub Popillae japonica and Hototricha sp. For pathogenic fungi, a commercial preparation of Verticillium lecanii is available for control of aphids, thrips and whitefly under the greenhouse conditions.

Botanicals- There are certain weeds such as Lantana, Tulsi, Notch, etc., which act as repellants to many insect pests. Some trees such as pungam, wood apple and Annona, and their byproducts have insecticidal values for controlling diamondback mothd, whiteflies, leafhoppers and aphid infestation. Commonly used plants are Neem (Azadirachta indica), Pungamia (Pungamia glabra) and Mahua (Madhuca Indica). Neem seed kernel extract (2-5%) is effective for insects like rice cutworm, diamondback moth, rice BPH, tobacco caterpillar, aphids and mites.

Trap Cropping

Trap crops protect the main cash crops from pests and insects, which can form the same or different family groups. Their advantages are lesser use of pesticides, cheaper than pesticides, preservation of

the indigenous natural enemies, improvement of crop quality, and conservation of soil and environment.

Table 3.7 Trap crops and pest control

Trap crops	Maincrops	Methods of planting	Pests controlled
Alfalfa	Cotton	Strip intercrop	Lygus bug
Basil & marigold	Garlic	Border crop	Thrips
Castor plants	Cotton	Border crop	Heliotis sp
Chervil	Vegetables/ ornamentals	Among plants	Slugs
Chinese cabbage, mustard, & radish	Cabbage	Planted in every 15 rows of cabbage	Cabbage webworm, flea hopper & mustard aphid
Beans & other legumes	Corn	Row intercrop	Leafhopper, leaf beetles, stalk borer & fall armyworm
Chickpea	cotton	Block trap crop at 20 plants /sqm	Heliotis sp
Collards	Cabbage	Border crop	Diamondback moth
Corn	Cotton	Row intercrop, planted in every 20 rows of cotton or every 10-15 m.	Heliotis sp
Cowpea	Cotton	Row intercrop in every 5 rows of cotton	Heliotis sp
Desmodium	Corn, cowpea & millet sorghum	Row intercrop	Stemborer & striga

Behavioral Methods

They include the use of Pheromones, fairomones, etc.

- Pheromones are ectohormones which are secretted by the organisms, which are particular, nontoxic, biodegradable and compelling at low application rates. Manufactured sex hormones are utilized for observation, checking and control of numerous Lepidopterous irritations, for example, spotted bollworm, tobacco caterpillar, potato tuber moth, diamond dark moth and leaf envelope.
- Fairomones are unpredictable mixes that summon social reaction which deliver either by the host plant or by the host creepy crawly. From the host plant, they can viably be used to mass snare bother species and monitoring.

Biological Methods

They include the utilization of any organism for the control of insects, pest diseases and weeds, which means using biotic agents.

Bio Intensive Pest Management (BIPM)

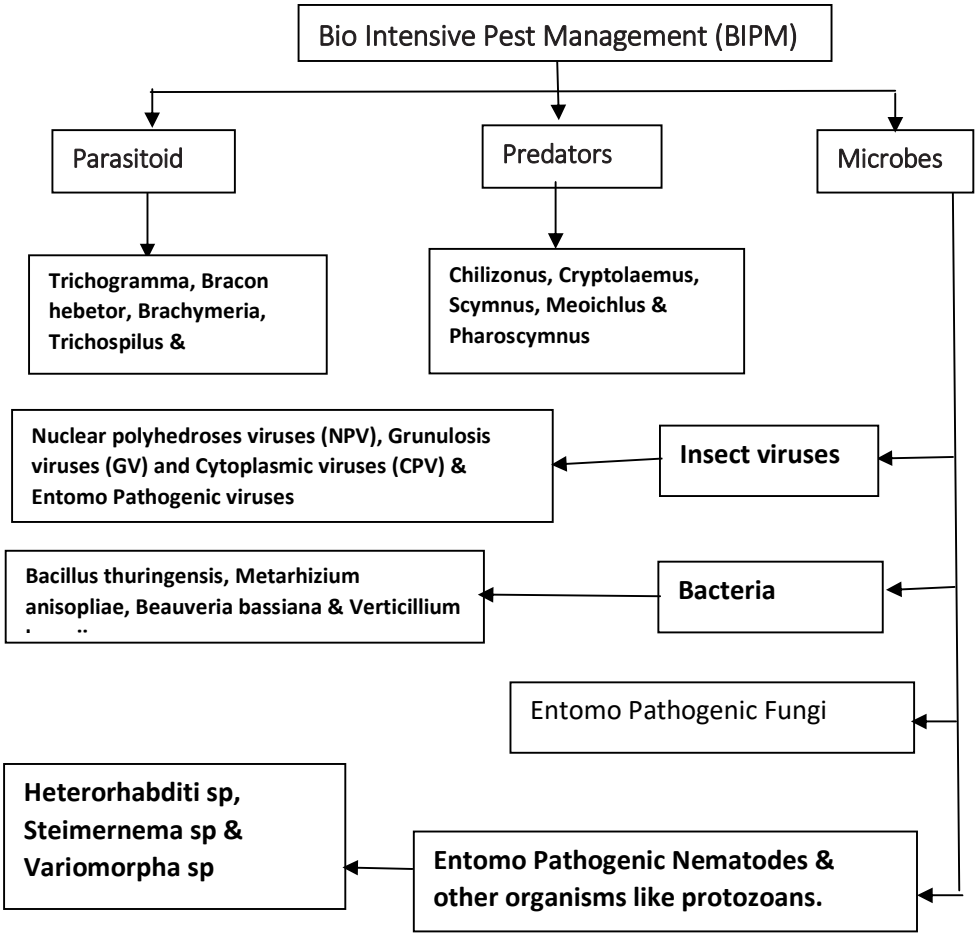


Fig. 3.13 Bio Intensive Pest Management (BIPM)

BIPM is a pest management programme where natural enemies of the crop pests from the core component are assigned. They are divided into three categories, viz.,

- Parasitoid,
- Predators, and
- Microbes causing diseases in the insects.
- Parasitoids are insects, either equal or lesser than the size of the host insect pest, and need at least one stage of their life cycle inside the host system. Examples are Trichogramma, Braconhebetor, Brachymeria, Elasmus, Eribor, Trichospilus, Chelonus and Tetrastichus.
- Predators are those insects that are generally bigger than the host and feed on several of the pests by predating externally. They consume various insect pests in their life cycle.

Table 3.8 Predators and their preys

Predators	Preys
Chilizonus, Cryptolaemus, Scymnus, Meoichlus & Pharoscymnus	Mealy bugs, coccids, scales, mites on citrus, grapevine & guava
Mirid predator Crytorhinus	Brown plant hopper of rice
Insect predator Chrysopa	Aphids, mealybugs & young caterpillars
Chrysoperla sp	Soft-bodied insects such as aphids, leafhoppers, etc.
ladybird beetle	Aphids & mealybugs
Spiders	Varied insects, especially in the rice ecosystem

- A microbial organism is capable of causing diseases in insects as a result of the loss of their appetite, physiological disturbances and ultimately death of the insect.
- Nematode pest management is by using biotic agents.

To Do Activity

List the Integrated Pest management activities for the insect pests of your regional cropping system.

References

- Biswas T.D. and S.K. Mukherjee. (1994). *Text Book of Soil Science*, Tata McGraw Hill publishing company Ltd., New Delhi.
- Brady, N.C., and Weil, R.R. 1999. The nature and properties of soils. 12th edition. Prentice-Hall, New Jersey, USA. Pp. 881.
- Chandrasekaran B, Annadurai K and Somasundaram E, (2010).Irrigation and Water Management A textbook of Agronomy, New Age International (P) Limited Publishers.
- DAS P.C. (2000). *Manures and fertilizers*, Kalyani Publishers, New Delhi.
- Dastane NG., (1972). *A practical manual for water uses research in agriculture*, Navabharat – Prakashan, Pune.
- Dumanski and Peiretti (2013). *Modern concepts of soil conservation*, International Soil and water conservation research, Vol 1, No 1, 2013, pp 19-23
- FAO. 1966. Proceedings of the FAO Symposium on Integrated Pest Control, Rome, 1965. Rome, FAO.
- FAO. 2001, Defining Conservation Agriculture. In: The Economics of Conservation Agriculture, FAO, Rome, Italy. www.fao.org/docrep/004/Y2781E/y2781e03.htm
- Gupta O.P. (1998). *Weed management - Principles and Practices*. Agro Botanical Publishers, Bikaner.
- Hudson, N. 1995. Soil conservation. BT Batsford Limited, London. Pp. 391.
- IAASTD. 2009. Agriculture at the crossroads, by B.D. McIntyre, H.R. Herren, J. Wakhungu & R.T. Watson, eds. Washington DC

- IARI, (1977). *Water requirement and irrigation management of crops in India*, WTC, IARI, New Delhi.
- Irrigation Scheduling criteria, Irrigation scheduling for crops | Agristudent.com | Agristudent.com, retrieved from https://agristudent.com/how-to-do-irrigation-scheduling-for-crops-agristudent-com/
- Lal, R. 1990. Soil erosion in the tropics. Principles and management. McGraw Hill, Inc., New York, USA. Pp. 580.
- Lewis, W.J., van Lenteren, J.C., Phatak, S.C. & Tumlinson, III, J.H. 1997. A total system approach to sustainable pest management. Proc. Natl. Acad. Sci., 94(1997): 12243–12248.
- Mandal R.C. and P.K. Jana, (1998). *Water resource utilization and micro-irrigation; Sprinkler and Drip system*, Kalyani Publishers, Ludhiana
- Misra RD., and M. Ahmed, (1987). *Manual on Irrigation Agronomy*, Oxford and IBH publication, New Delhi
- Pimentel, D. & Levitan, L. 1986. Pesticides: Amounts applied and amounts reaching pests. BioScience, 36(2): 86-91.
- Rana, S. 2010. Global agrochemical market back in growth mode in 2010. Agrow (www.agrow.com).
- Rao V.S.(1994). *Principles of Weed Science*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Smith, R.F. & Doutt, R.L. 1971. The pesticide syndrome– diagnosis and suggested prophylaxis. In C.B. Huffaker, ed. Biological Control. AAAS Symposium Proceedings on Biological Control, Boston, December 1969, pp. 331-345. New York, Plenum Press.
- Stern, V.M., Smith, R.F., van den Bosch, R. & Hagen, K.S. 1959. The integrated control concept. Hilgardia, 29: 81-101.
- Thompson L.M. and F.R. Troeh, F.R. (1973). *Soils and Soil Fertility*, McGraw Hill Publishing Co., London
- Troeh, R.F., Hobbs, J.A., Donahue, R.L. 1991. Soil and water conservation. Second edition. Prentice, Englewood Cliffs, New Jersey, USA. 529.
- Wood, B.J. 2002. Pest control in Malaysia's perennial crops: A half-century perspective tracking the pathway to integrated pest management. Integrated Pest Management Review, 7: 173-190.

Model Questions

1. What is the soil environment and how has it been classified?
2. Explain various methods of irrigation and irrigation water management.
3. Differentiate between manures and fertilizers with special reference to biofertilizer.
4. What are the methods of application of fertilizers?
5. What is the weed control mechanism? Discuss its methods with a comparative analysis.
6. What are the Integrated Pest management practices and BIPM?

Chapter 4 Field Crops, Farm Machinery and Seed Technology

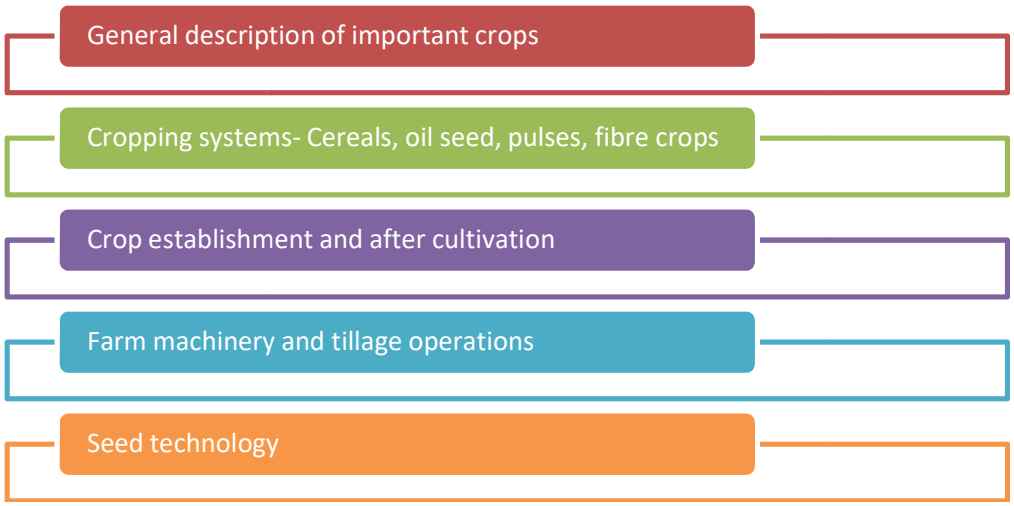
Introduction

Agriculture plays an important role in the Indian economy, where crops especially food crops has lots of contribution in the food self-sufficiency. Almost 70 % population of the country depends on the agriculture for food as well as economic dependency. The sector provides livelihood and occupation in the rural area particularly. The cultivation of crops in India depends on the erratic climatic conditions as well as edaphic factors. The crops are the plants which are cultivated and sown in the commercial manner. Due to the diversity of the nation in terms of climatic and geographic components, there are various cropping systems followed on the basis of its suitability. Cropping pattern refers about the area under various crops in a particular place and a particular point of time. The cropping pattern is a dynamic concept, which varies according to the region. The variations are on the basis of the geo-climatic, socio-cultural, economic, historical and political conditions of the region. Cropping pattern of a region is influenced by various factors such as edaphic, climatic and precipitation of the region. Crop establishment system is the techniques to improve the productivity of land, with the help of proper soil management practices. Under crop establishment the crop rotations, cropping pattern can be changed which will be suitable according to the locality. In field crops the food grain are the staple food crops, which contributes to commercial agriculture economy. The edaphic factors, which include soil played an important role in establishment and growth of crop. There are various issues related to the soil condition such as soil texture, structure, compaction, acidic soil, alkaline soil, which all require soil management and techniques to conserve. Farm machinery and equipment has lots of role in terms of upgradation of quality and productivity. Due to the farm mechanization, the productivity of food products has been improvised in the efficient manner. Other than these, the seed is the most important input for the agriculture, where seed technology has lots of contribution to improvise the performance.

Objectives

- To explain various field crops in India
- To explain diversified cropping system of the country
- To examine various crop establishment techniques and post cultivation techniques
- To explain the farm machinery, tools, equipment and tillage operations
- To explain the seed techniques and seed certification

Chapter Structure



4.1 General Description of Important Crops

In Indian economy agriculture plays an important role, which includes various farming practices, such as crops farming, animal husbandry, pisciculture, agro forestry etc. The contribution of agriculture is about 15.87 % in GDP along with all these sectors such as forestry, fisheries, and allied sectors.
The climate, weather and edaphic features are suitable for the crops in India. On the basis of season for agriculture India has three seasons, namely Rabi, Kharif and Zaid season. India is the top most producers of various crops across the world. There can be various ways of classification of crops such as based on area, based on season, based on economic value of crops.

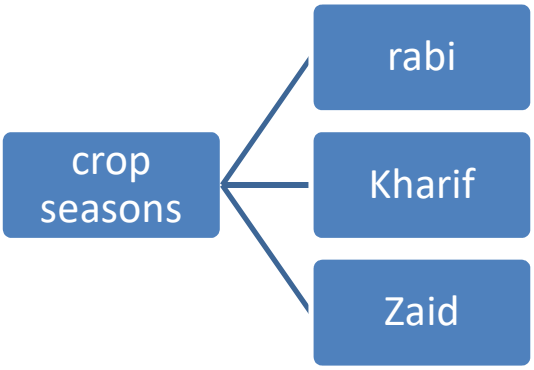


Fig 4.1 Seasons of crops in India

Table 4.1 Details of crop season in India

Particulars	**Kharif crops**	**Rabi crops**	**Zaid crops**
Sown	June-July (rain begins, monsoon crops)	October-November	March- June (Between Rabi and Kharif crops)
Harvest	September- October	April-May	Early maturing crops
Requirement	Water and hot weather to grow the crops	Warn climate for seed germination and maturation. Cold climate for growth	
Examples	Rice, Jowar, Maize, Cotton, Ground nut, Sugarcane, Jute, Turmeric, Pulses	Wheat, oat, Gram, barley, Tomato, Oilseeds, Onion, Potato, Barley, Sunflower, Sesame, Mustard, Rapeseed	Cucumber, Watermelon, Muskmelon, Moong dal, Bitter gourd

Crops can be divided on the basis of its economic value and it can be classified into four broader categories. These are food crops, cash crops, plantation crops and Horticultural crops. Field crops include wheat, maize, rice, millet, pulses. Cash crops include sugarcane, tobacco, cotton, Jute and oilseeds etc. Plantation crops include coffee, tea, coconut and rubber crops, while horticulture crops include fruits and vegetables.

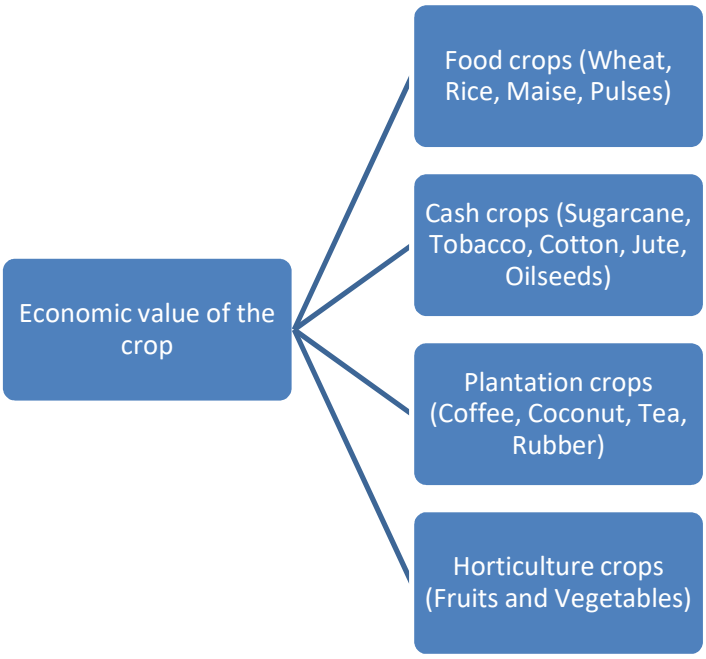


Fig 4.2 Categories of crops on the basis of economic value

Important Crops in India

The major crops in India are rice and wheat as a staple food crop. Rice is the tropical crop which can be grown in throughout the year in different parts of the country, which depends on the moisture content of the atmosphere and rainfall rate, precipitation for irrigation.

Table 4.2 Major crops in India

Particulars	**Rice**	**Wheat**
Types of crops	Kharif, Rabi	Rabi
Varieties	Aman, Sali, Afghani, Aus, Paula, Boro	Kalyan Sona, Sonalika, Heera
Temperature required	24 ^{0}C	17-20 °C
Techniques used	Transplantation techniques, SRI techniques, Japanese transplantation technique	-
Rainfall	150 cm	20-100 Cm (best 75cm)
Soil type	Clay/ laomy	Sandy loam, clay loam
Highest producer	West Bengal	Uttar Pradesh
Major producers	Uttar Pradesh, Andhra Pradesh, West Bengal, Assam, Punjab, Bihar, Odisha, Haryana, Tamilnadu, Chhattisgarh	Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Bihar, Maharashtra, Gujarat, Rajasthan, Uttarakhand, West Bengal
Highest per hectare yield	Punjab	Punjab,
Research Centre	Cuttack, Odisha	Karnal, Haryana

India is the second largest producer of rice in the world, and largest area in world under rice cultivation. In green revolution, the revolution has main focused of wheat, so the productivity is less compared to the wheat. The conventional rice field is called as paddy field and it requires flooded field with 10-12 cm deeper in the early stages of rice production process.

Wheat is the rabi season food crop, which is second most important food crop in India. India is the second largest wheat producer throughout the world. Wheat is comparable more conducive to grow on various climatic fluctuations and growth conditions.

Millets/ Coarse Crops

Coarse cereals or millet crops are the crops which can be short duration and can be grown in the warm weather and used for food and fodder. The major millet crops are Jowar, bajra, Ragi, Finger millet etc. The millet crops can be grown majorly in the dry land that is why it is called as the dry land crops also because it can be grow at very low rainfall areas, which can be 50-100 cm rainfall. The coarse cereal crops are less deficient for the soil deficiencies too and it can be grown in inferior alluvial soil of loamy soil. The states, which are majorly producing the millet crops are Maharashtra, Karnataka and Rajasthan. These are also the top three producer states for the coarse cereal crops.

Pulses - Most of the pulses comes as a leguminous crops and it is the major source of protein for the vegetarian population. The common pulse crops of India consist gram, Tur of Arhar, black gram, green gram, horse gram, peas etc., where Tur dal and gram are the most commonly used pulses.

Cash Crops

Cash crops in India include various crops like major cash crops are sugarcane, cotton, tobacco, groundnut and jute.

- Sugarcane is the one of the important cash crops, in which India is the 2nd largest producer throughout the world. Sugarcane is the crop which requires long rainy season for grown up to 7-8 months. Sugarcane was grown traditionally in Northern India, but now it has shifted to southern India also. In Northern India, the subtropical varieties of sugarcane have low sugar content, which was one of the causal factors to shut down the sugar factories in the winter season. While in case of southern India, due to tropical variety and coastal areas the high sugar content in the sugarcane crops along with high yield.

- Cotton is another cash crop, which is fibrous crop and known as white gold. Cotton is the tropical and subtropical kharif crop. India stands 3rd in cotton production throughout the world. Cotton is the crop which can be grown in dry land but at the time of maturity of the crops, cotton requires regular supply of water.

- Jute is the tropical crop, which requires hot and humid climate for production. Jute is one of the best fibrous crops in terms of cultivation and as a natural fibrous use. Around 85 percent of the jute produced in the areas of Ganges Delta region.

- Groundnut is one of the important oilseed crops, which can grow in both the seasons Rabi and Kharif, but almost 90-95% area is being under the Kharif season. Regarding the climatic condition, groundnut can flourish in the tropical climate, it requires 20-30°C temperature and

50-75cm rainfall. Ground nut is the crop, which is highly susceptible to frost, continuous rainfall, drought and stagnant water, but it needs dry weather at the time of ripening of the crops. Groundnut requires well dried, sandy loam, red and black soil for production. Out of all the oilseeds, groundnut accounts for half of the major oilseeds in India. India is the second largest producer of groundnut in the world. The major groundnut producing states are Gujarat, Andhra Pradesh and Tamilnadu.

Table 4.3 Cash crops in India

Particulars	Sugarcane	Cotton	Jute
Types of crop	Kharif, Rabi	Kharif	Zaid
Temperature	20-27 °C	21-30 °C	24-35 °C
Rainfall	75-150 cm	50-100cm	125-200cm
Soil type	Clayey loam/ Black cotton soil, red loamy and brown loamy soil	Black soil with high water retention ability	Sandy and clay loam
Producers	Uttar Pradesh, Maharashtra, Karnataka, Uttarakhand, Bihar, Tamil Nadu, Andhra Pradesh, Punjab	Maharashtra, Gujarat, Andhra Pradesh, Haryana, Madhya Pradesh, Punjab, Rajasthan, Odisha	Bihar, West Bengal, Assam, Andhra Pradesh, Meghalaya, Odisha, Nagaland, Uttar Pradesh, Tripura
Highest producers	Uttar Pradesh	Gujarat	West Bengal
Highest per hectare yield	Tamil Nadu		West Bengal
Research Centre	Lucknow	Nagpur	Kolkata
Highest producing country	Brazil	China	India
Varieties		Long staple, Medium staple, short staple	White Jute, Tossa jute

Plantation Crops

Regarding the plantation crops in India, tea and coffee are the major crops. Tea is the evergreen plant, which grows in tropical and subtropical climate. Tea is one of the labour-intensive crops where almost 50 % work is being performed by women. For tea production, shade is more conducive to grow. Commercialization of tea has been initiated from the British time. India is the 2nd largest producer as well as consumer of tea in the world. Tea production can be done in the slopy land, because it requires high rainfall, but its roots cannot tolerate water logging conditions.

Coffee is another plantation crop, which grows under shade and commonly two tiers of shade. The suitable altitude for growing coffee ranges between 1000-1500m above sea level for Arabica and 500-1000m for Robusta. Arabica is the premier coffee and Robusta is the lower quality coffee. Arabica and Robusta coffee varieties are planted in well-drained soil which is rich in organic matter. The slopes of Arabica are gentle to moderate and Robusta are gentle to fairly level.

Table 4.4 Plantation crops in India

Particular	Tea	Coffee
Temperature	20-30 °C	16-28°C
Rainfall	150-300cm	150-250cm
Soil type	Loamy soil (acidic in nature, rich in organic matter)	Well drained forest laom
Major producers	Darjeeling, Assam, Meghalaya, Kerala, Himachal Pradesh, Tamil Nadu and Karnataka	Tamil nadu, Karnataka, Kerala, Telangana, Andhra Pradesh, Odisha, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur
Highest producers	Assam	Karnataka
Research centre	Assam china	
Highest producing country		Brazil
Varieties		Arabica and Robusta

Spices

In India, spices have been known since ancient times. The major locations for spices growth are western ghats and other hilly areas. The suitable altitude for growth is 1000-2000m above mean sea level. Regarding the climatic condition, the suitable temperature range is 10-30 °C and precipitation is 200-300cm. The suitable soil type is loamy soil or laterite soil. Kerala and Karnataka are major spice producing states.

Table 4.5 Spices and production state

Spices	State of production
Cardamom (Queen of Aromatic Spices)	Assam, Kerala, Tamil Nadu
Pepper (king of spices)	Kerala
Chilies	Rajasthan, Andhra Pradesh, Karnataka, Tamilnadu
Turmeric	Andhra Pradesh, Karnataka, Tamil Nadu
Nutmeg	Kerala
Arecanut	Kerala, Tamil nadu, Tripura, Assam
Coconut	Kerala, Tamil nadu, Karnataka, Andhra Pradesh
Cinnamon	Kerala
Clove	Kerala
Ginger	Kerala, Meghalaya, Sikkim

To Do Activity

List the crops with the classification of staple food crops, oilseed crops, fibrous crops, pulses crops, cash crops and plantation crop of India.

4.2 Cropping Systems- Cereals, Oil seed, Pulses, Fibre Crops

Cropping pattern is the sequence of crops as well as spatial arrangements of crops in a period of time in the given particular area. There are multiple factors governs on the field for the choice and selection of the crops. The factors are as follows

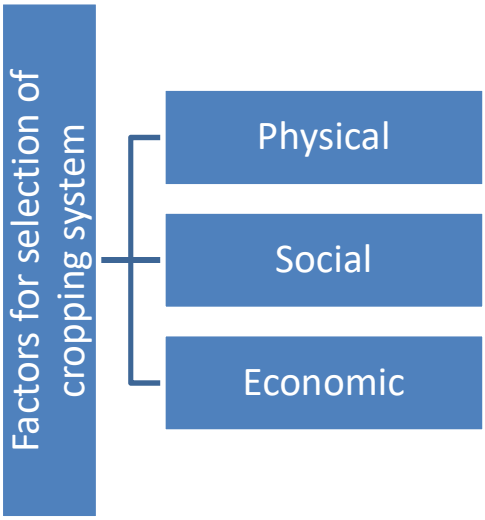


Fig 4.3- Factors for selection of cropping system

A cultivators or farmer consider the factors and choose some number of crops throughout the year and cultivate those in the farm and rotate the same combination of crops over many years, which can result into the multiplicity of cropping system. The sequencing of production may get change over the period of time and space. There is numerous cropping system almost 250 has been identified across the country, but it has been estimated that out of all only 30 cropping systems are majorly adopted. Except in few areas, where the monocropping system is followed because of more moisture of heat condition.
There is lots of diversity in cropping systems existing in the rainfed and dryland areas. This is due to the risks involved in the cultivating in the large area under a particular crop. While in case of irrigated area where there is assurance of irrigation facilities only some of the cropping system is followed and which contribute in the significant amount for food productivity at the national level. In India, the agriculture decisions are taken on the basis of various factors such as soil types and climatic conditions. The climatic factors as well as edaphic factors determine the agro-ecological setting for growth and conducive situations required for the crop for cultivation.

There are three crop seasons in India i.e. Rabi, Kharif and Zaid. Kharif season started with Southwest monsoon, where tropical crops such as Rice, cotton, Jute, Jowar etc cultivated. Rabi season comes with the start of onset of winter in October- November, while Zaid is a short duration summer cropping season, which begins after the Rabi season.

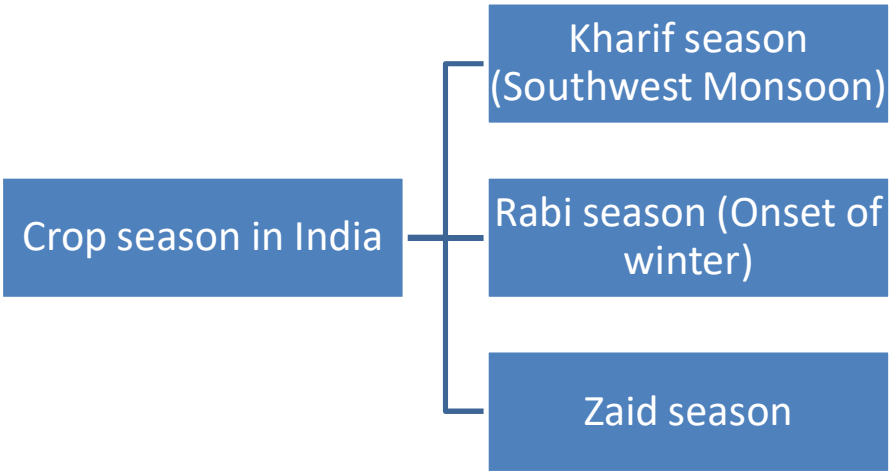


Fig 4.4 Crops season in India

Cropping System in India

There are mainly four cropping system in India, these are Rainy season cropping system, Winter cropping system, Plantation and other commercial crops and Mixed cropping. Rainy season cropping system described about the rice-based cropping system, kharif crops other than rice, groundnut-based cropping system and cotton-based cropping system.

- In case of Rice based cropping system, rice crops grown in the high rainfall areas where irrigation facilities are available which can ensure the crop productivity. Almost in more than 80 percent places rice can be grown in the month of June to September. Such as in Meghalaya, rice crop grows with other crops such as cotton, vegetable and fruits. In the states like Odisha, coastal Andhra Pradesh, Bihar, Jharkhand and Assam rice crop is grown with jute. In Bihar, the crops grown with jute, sugarcane, pulses and oilseeds are grown.
- In case of Kharif, cereals other than rice such as maize -based cropping system, sorghum-based cropping system, and Pearl millet-based cropping system. Maize can be grown in the places, where high rainfall along with more soil moisture content in soil available with good drainage facility. Sorghum can be grown in the areas, where medium rainfall occurs, which is popular in Maharashtra and Madhya Pradesh. The crops can be taken along with sorghum, pulses, groundnut, and small millets. Pearl millet is more drought resistant which is preferred in the areas where less rainfall occurs and light textured soil available. This system is very common in the states like Gujarat, Uttar Pradesh, Rajasthan and Maharashtra.
- Groundnut-based cropping system is popular in Andhra Pradesh, Gujarat, Karnataka, Tamilnadu and Maharashtra.
- Cotton-based cropping system is common in Gujarat, Maharashtra, Andhra Pradesh and Punjab. Cotton can be grown with other crops such as sorghum, groundnut, pulses and wheat in Kharif and rabi season. In case of irrigation-based areas, cotton can be grown with other crops like sugarcane and rice.

Winter cropping system includes wheat and chickpea-based cropping system and rabi sorghum-based cropping system. In rabi crops wheat, barley, oats, sorghum, and chickpea are the main crops, while wheat and chickpea are the crops related to the subtropical region of Northern India, while rabi sorghum is grown in Deccan. In wheat and chickpea-based cropping system wheat and chickpea considered as substitute under the identical situation. The crops can be grown in the cropping system

are oilseeds, cotton, small millet etc in Madhya Pradesh, while in Punjab, the crops like maize, cotton and Pearl millet can be grown. Rabi sorghum-based cropping system is very common in Maharashtra, Karnataka and Andhra Pradesh. The alternative crops like pearl millet, oilseeds, tobacco and pulses can be grown as alternative crops grown in Maharashtra.

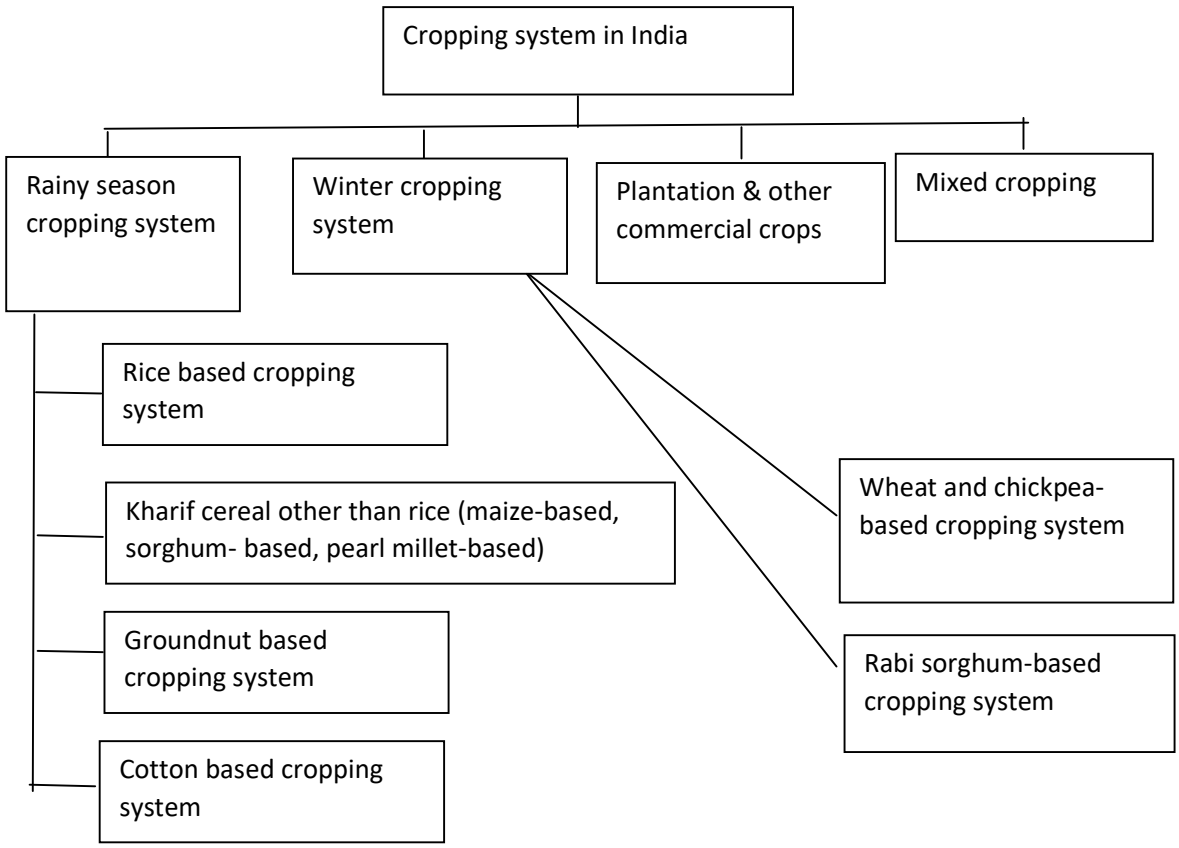


Fig 4.5 Cropping system in India

Plantation and other commercial crops include sugarcane, tobacco, potato, jute, tea, coffee, coconut, rubber, spices and condiments. Spices and condiments are more important, which may be seasonal or annual or perennial. The areas occupied by these crops are comparatively less than the food crops, but from the commercial point of view it is more relevant. Apart from that, there are certain horticultural crops such as fruits can be grown. For instance, in jute growing areas rice can be as alternative crop. In some of the states like Punjab, Haryana, Bihar, Uttar Pradesh, Maize and wheat are the rotation crops with sugarcane crop.

In mixed cropping the crops like pulses, oilseeds are grown with maize, sorghum and pearl millet. In case of low land rice which can be grown as invariably but in upland rice, the mixture is there. Like in non-irrigated areas of North in the rabi season wheat, Barley and chickpea can be used to mixed.

In the cropping system the existing systems are in such as crop rotation, multiple cropping, mixed cropping and strip intercropping. In Crop rotation, crops are changed in the field at every year as per the

plan of crop sequence, rather than growing same crop on the field. Multiple cropping is about to grow two or more than two crops in the same field in the given period of time with the definite row arrangement. It includes intercropping, mixed cropping and sequence cropping. While strip cropping is the system where two or more than two crops are planted in the same field in the alternative rows. Monocropping or monoculture is the system where only one crop is grown in the piece of land year after year. In the agricultural practices in India, there is lack of intensive planning regarding the agricultural practices, because of India are the diversified in terms of agroclimatic zone.

Table 4.6 Most Efficient cropping system in India

Intercropping	Mono cropping	Crop sequence
Wheat+ Raya	Rice	Rice-Wheat
Maize+ Peas	Wheat	Maize- wheat
Pearl Millet +Gram	Maize	Groundnut+ Barley/ Wheat
Toria+ Gobhi sarson	Sorghum	Pearl Millet- Mustard
Mustard + Gram	Groundnut	Gram- Mustard
Sugarcane+ Potato	Mustard	Cotton-Wheat
Sugarcane+ French bean	Redgram	Coconut- Groundnut
Maize+ Groundnut	Gram	Sorghum- Gram
Sorghum+ Red gram	Cowpea	Sesame- chickpea
Sunflower + cotton	Soybean	Soybean- Safflower
	Sugarcane	Sugarcane- Pulses
	Cotton	

To Do Activity

- Discuss various cropping system in Rabi, Kharif and Zaid season in India.
- List down the suitable cropping system followed in your locality.

4.3 Crop Establishment and After Cultivation

Crop establishment is one of the crucial steps to achieve maximum potential yield. Where the timeline of sowing the crop is one of the crucial factor, which helps in the evenly establishment as well as uniform plant establishment and plant stand. A uniformly established crop is the foundation of high yield.

Principles of Crop Establishment

Crop establishment has the goal to establish a uniform plant stand in order to achieve the maximum yield. The system of Crop establishment includes various operations such as plough, min-till, no tillage or direct drill.

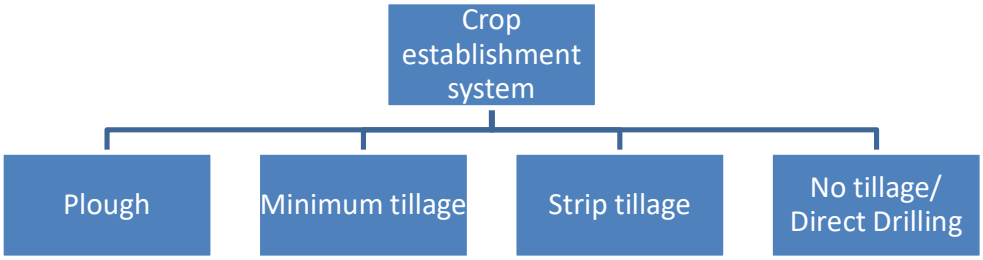


Fig 4.6 Crop establishment system

Plough

Ploughing is the process of breaking, loosening the soil and turning it over for uprooting weeds and aerating the soil. It loosens the soil so that roots of crops can penetrate the soil easily. Ploughing is the very common technique for crop foundation. This is a traditional soil reversal strategy at a profundity of 9 to 12 inches. Furrowing is a strategy for Crop foundation which is more dependable in the atmosphere and goes about as a decent weed control technique moreover. Alongside every one of these advantages there are sure downsides, for example, there are confirmations of soil disintegration run off and helpless penetration rate which could cause the advancement of a furrow skillet.

Minimum Tillage

Minimum tillage as one of the methods of Crop establishment which sometimes referred as conservation tillage which helps to reduce the amount of tillage process by at least 40% related to the amount of tillage process by soil disturbances required to establish up crop in the conventional manner.

Strip Tillage

Strip tillage is the method of Crop establishment where it is similar to direct drilling but sometimes there are certain disturbances at the level of soil. Strip tillage should only cultivate less than one third of the field area where seeds can be sown in the streets by disturbing the soil and the area between the strips can left as untouched area. With the method of this strip till is there are certain problems like is sterile brome, black grass and wild oats.

No Tillage or Direct Drilling

No-Tillage farming- No-tillage farming also called zero tillage or direct drilling. No-tillage farming is the practice where the cultivation of crops is done without soil disturbance by tillage. There are certain advantages of no-tillage farming, such as it helps to reduce soil erosion, particularly in the case of sandy soil or in slopy terrain. No-tillage farming increases the soil infiltration rates, retention of organic matter in the soil, and augments the nutrient cycle in soil. In contrast, the traditional no-tillage farming, herbicides are used for weed control, while in the organic system, there are various strategies used for weed control such as mulching, plantation of cover crops etc.

Post Cultivation Practices

After the establishment of Crop there is proper care which is required to control the weeds. For weed control the soil around the plant can be disturbed and it can provide aeration. The post cultivation practice includes various operations such as there should be proper measures required to avoid lodging of tall growing crops. There are certain special operations required to

introduce or induced the crop growth and to get large harvest of economic produce. All these practices which carried out after the establishment of Crop that is called as after cultivation practices or post cultivation practices. These after cultivation practices include hand weeding, hand hoeing, earthing up, detrashing, propping, topping, desuckering and quartering.

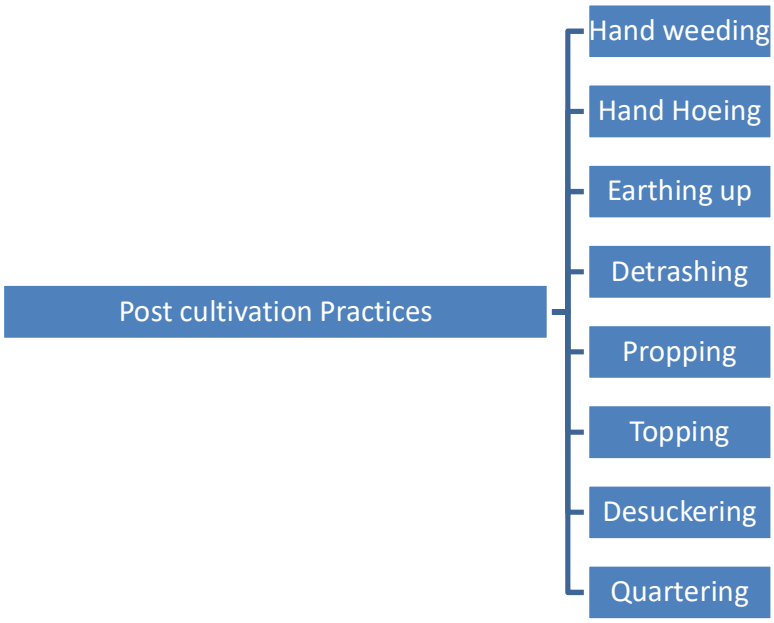


Fig 4.7 Post cultivation practices

There are certain other practices such as irrigation, manuring and plant protection which also include in the after-cultivation practices over aftercare measures. Hand hoeing, weeding, earthing up operations are also carried out but in the standing crop these are called as intercultural practices.

Weeding

Weeding is the practice which is about removal of weed. This practice does not affect the soil which is beneficial for the plant growth. This reduces the spawn of weeds.The purpose of weeding is to clear the huge amount of plants from the new agricultural field. Wedding is the operation which can be done manually rather than using the mechanical equipment and it needs to be done on a regular basis. The primary focus of wedding as an operation is mechanical control first then chemical weed control can also be used as an additional method in certain cases. There are various other operations such as mulching is one of the operations where the use of cover crops as well as the other techniques like false seed bed, removing of infected crops, close seasons, pairing, using clean tools that are also a preventive measure for weed control.

Hoeing

In some soils, the surface of soil can get harder after the rain fall or kind of crust formation is there on the surface of soil water rises in the crest as it rises in lumps of earth. The crust of earth can be broken to prevent the water rising this is called as hoeing. The rain that falls on a well hoed soil that goes in easily does not create run off situation on the surface which doesn't make waste also. Hoeing is the operation which can be done with the help of hand hoe or it can be done with the help of an animal

drawn cultivator. Sometimes weeding is the operation which can help or which can solve both the purpose, it can help to get rid of from the weeds as well as it can break up the soil crust.

Hilling

Hilling, earthing up or ridging is the technique in agriculture and horticulture of piling soil up around the base of a plant. It can be done by hand (usually using a hoe), or with powered machinery, typically a tractor attachment. Hilling buries the normally above-ground part of the plant, promoting desired growth. This may encourage the development of additional tubers (as with potatoes), force the plant to grow longer stems (leeks), or for some crops (chicory, leeks, asparagus etc.) this blanching technique keeps the stems or shoots pale and tender, or influences their taste. Hilling may also be used to stabilize the stems of crops which are easily disturbed by wind.

Detrashing

Detrashing involves removal of unwanted bottom dried and yellowish green leaves on fifth and seventh month after sugarcane planting. The bottom most green leaves are parasitic on the upper productive leaves and drain out the food reserves (photosynthates) which otherwise could be used for stalk growth. Therefore, in sugarcane it is important to remove the lower dry and green leaves. Detrashing helps in maintaining clean field which minimizes rodents, rats, squirrels in the field that may otherwise cause damage to the crop, enhances air movement and enriches CO2 within the crop canopy providing an ideal micro-climate for unrestricted growth of cane, availability of more food material for stalk growth, reduces the problem of infestation of several insect-pests like scales, mealy bug, white flies etc, reduces bud sprouting due to accumulation of water inside the sheath and detrashed leaves can be used as a mulch for moisture conservation or composting. In view of avoiding the direct contact with hands and sugarcane leaves and also to reduce the drudgery involved in detrashing, an ergonomically improved sugarcane detrashing tool was designed and developed with a substantially reduced weight.

Propping

The operation of tying the leaves together using the bottom dry and green leaves is known as propping. It is done to check lodging of cane. Usually the trash without removing from the cane is twisted to form a sort of rope and cane stalks are tied together. As a rule the waste without eliminating from the stick is wound to shape such on a rope and stick stocks can be integrated. This is called as junk bend trimming it very well may be done either for each column or two lines can be united and tied. In India in specific cases, bamboo shafts can be utilized and propping should be possible in specific pockets, yet it tends to be extravagant so in the region where stick top development is hefty and when wind speeds are high, propping becomes important practice to forestall dwelling. It assists with caning breakage and loss of stock number at gather and it can assist with improving the stick yield. Propping assists with lessening the pervasion of creepy crawly and vermin which makes organisms housing and harm sticks. The stick quality relies upon the bed growing prompting diminish scale quality, airborne root arrangement additionally influences stick quality.

Topping

Topping is a process by which a mower or similar implement is used to "top", or remove, the aerial part of a crop, in order to prevent seed formation and distribution onto the soil. In specific cases, a put aside crop spread is halted in July or August to prevent seed production and subsequent soil contamination leading to germination and regrowth.

Desuckering

Desuckering is the practice of green pruning that related to the grapevine foliage. It is made in the time

of vegetative activity of the plant and it includes removal of shoots that are not fruit bearing or it is called as suckers. The purpose of topping and desuckering is to change the energy and nutrients to the leaves for increasing its size and the final leaf is besides improvement in the quality.

Quartering

Quartering is the process isolating thoroughly mixed sample into four equivalent amounts of where the two inverse quarters are disposed of and the rest two quarters would we be able to blend and the cycle is rehashed until the ideal example size is gotten.

Thinning

Thinning is the process of removal of surplus plant. At the time of sowing the seed, one can put more than one seed in one hole when the seeds grow together then there are too many vegetative growth comes out of one hole. Then some plants must be taken out and rest of the plants can be left or to make it a better growth. As per the recommendations of agricultural professionals, the two best plants in each hole can be left. Thinning can be done when the plant has few leaves but before they are too big. While the pulling out the surplus plants the soil is being disturbed so it is necessary to press down again grounds the plant that is left.

To Do Activity

- List down the crops under each post cultivation practices performed.
- Discuss on the adverse effects on the crops, if propping, detrashing and desuckering is not performed as after cultivation practices

4.4 Farm Machinery and Tillage Operations

Farm machinery means all the vehicle, implements and attached units which can be designed and sold for direct used in farming, planting, cultivation and harvesting the farm products or it can be used in connection with the production of agricultural produce, livestock and poultry farm which can be operate by motor or animal power. It includes machinery, equipment, a structural material which can be used directly and exclusively or incorporated into the structure are the facility for collection, handling, storage, heating, cooling related to the operation. It doesn't include machine which can be used for any other purpose than agricultural operations like tyres, repair parts, tool, shop equipment, grain bin, fencing material or any other items. Agricultural implements a kind of machine which can be used for the farm to help with farming. The best example of this type of machine is tractor.

Common Farm Machinery Equipment

There is certain farm machinery equipment such as tractor, cultivator, plough, harrow, subsoiler, roller, seed drill, planter, sprayer, drip irrigation, combine harvester, mower, rice huller, winnower, hand milking machines.

Tractor

Tractor is one of the engineering vehicles which are specifically designed to deliver a high tractive effort at a slow speed for the purpose to perform the agricultural or construction operations. This is very widely used to describe the farm vehicle which provides the power and traction to mechanized agricultural task specialty tillage operations. Most of agricultural implements can be tied behind or mounted on the tractor so which helps to make a source of power if the implements are mechanize.

Cultivator

Cultivator is used for the secondary tillage, in one way the name refers the implement which appears the soil and it's dragged through it's linearly. There is another way to see the machine which used for the rotary motion of discs or teeth which can help to accomplish the similar results. Cultivator can still and pulverized the soil either before planting which can create aeration into the soil and prepare a smooth and loose seed bed or after the crop. It can begin growing or to kill the weeds, it can help to control and disturbances of the top soil which is very much related to the crop plant. Cultivator also disturbs the soil, but not in a manner which harrows is doing. Cultivators are designed to disturb the soil in a very careful pattern where is sparing the crop plants but disrupting the weeds.

Plough

A plough is a Farm implement which helps to loosen the soil or turning the soil before sowing the seed or before the planning stage. Apply traditionally drawn from oxen and horses between in now a day it can have wooden iron or steel frame with attached blades to cut and loosen the soil.

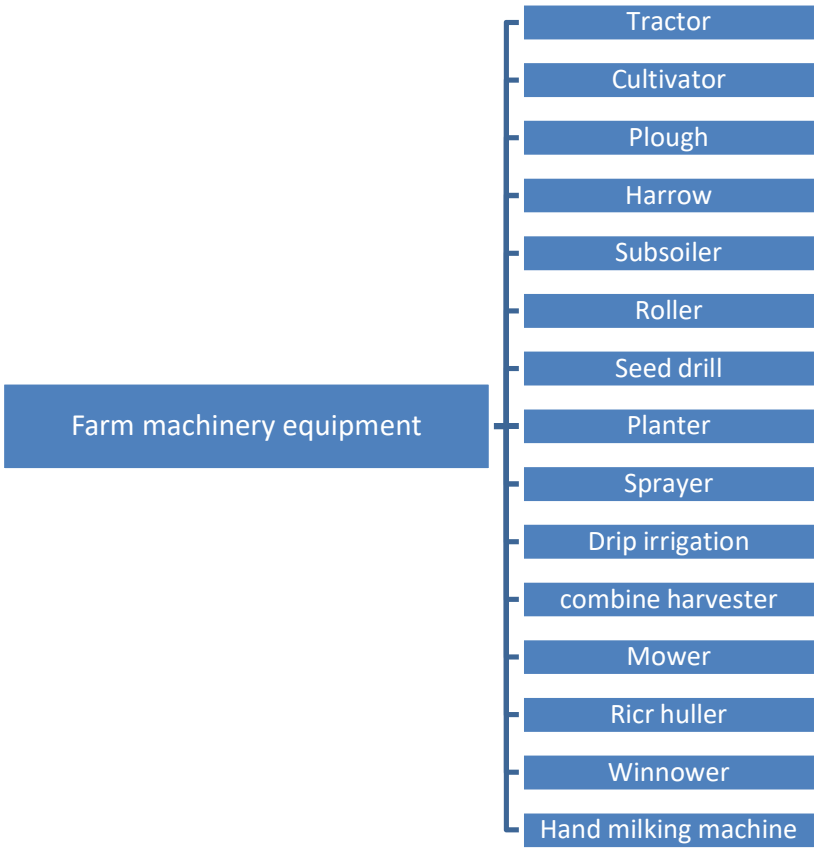


Fig 4.8- Farm machinery equipment

Harrow

In case of agricultural practices Harrow is one of the implements which help for the separating and smoothing the outside of soil. It assists with making the impact good ways from the furrow which is utilized for more profound culturing. Once in a while frightening is the cycle which can do in the field to follow the harsh completion left by the nerve racking tasks that is the thing that the motivation behind

nerve racking is by and large to separate blocks or chunks of soil and to give a last completion to a decent tilth and soil structure. Nerve racking is activity which is unique in relation to the cultivator thusly that it upsets the entire surface of the soil, for example, arrangement of seedbed as opposed to upsetting just thin path that skirt crop lines.

There are four general sorts of harrow, these are plate harrow, prong harrow, chain harrow, and chain disc Harrow. Where tine Harrows can include spring tooth harrow, drag harrow and spike harrows.

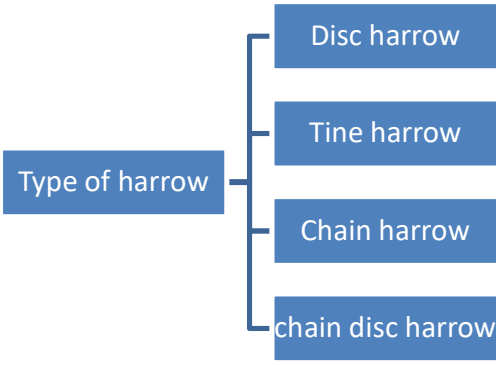


Fig 4.9 Types of harrow

Subsoiler

Subsoiler or level lifter is utilized for the more profound culturing, releasing and separating the soil at a profundity beneath the level work. The greater part of these sorts of apparatuses are separating and transform over surface soil into a profundity of 15 to 20 CM while a subsoiler can separate and slacken the soil to twice those profundity.

Roller

Roller is another agricultural tool which can be used for flattening of the land of breaking of the large clumps of soil specially after the ploughing or harrowing. Rollers are actually pulled by tractors or prior to make a nice addition there was a team of animals which was pulling the rollers so as well as the agricultural purpose rollers are used on some other pitches also like lawn or cricket pitch.

Seed Drill

Seed drill is a kind of device which sows the seeds for crop by positioning them into the soil and brings them on a specific depth. Seed drill helps us to ensure the placement of seed and its distribution evenly. The seed drill can sow the seed at a proper seeding rate and can ensure that seeds are covered by soil which can save the seeds from being eaten by birds or any other predators or being exposed and dried up to the sun. With the help of seed drill machine seeds can be distributed in rows, while the distance between seeds along with row cannot be adjusted by use of this machine so that is the distance between rows is typically set by the manufacturer.

Planter

Planter is the farm equipment which is towed behind the tractor which helps to sow the seeds into rows throughout the field. It can connect to the tractor with the draw bar or a three-point hitch. Planter can be lays down into the precise manner into the rows.

Sprayer

There is another device which can be used to spray the liquid. Sprayer can be commonly used for projection of water, weed killers, crop performance material, pest control chemicals for manufacturing and production line ingredient. In case of agriculture, the sprayer is a piece of equipment because it can use to apply various chemicals on the crops such as herbicides and pesticides, fertilizers etc. Sprayers range in size from manmade units to the trailed sprayers which can connect to the tractor.

Drip Irrigation

Drip irrigation is one type of micro irrigation system which is having potential to save the water and nutrients. It allows water to reach a drop down to the roots of plants so it can remove the wastage of water also. The purpose of drip irrigation is to put water directly to the root zone and minimize the evaporation process. The system distributes water through a network of valves, pipes and emitters. On the basis of the design, maintenance and operation a drip irrigation system can become effective or efficient other than the irrigation systems like surface irrigation or sprinkler irrigation.

Combine Harvester

Modern combine harvester or simply combine is one of the versatile machines which have been designed for effectively harvest a variety of grain crops. The name of this combined has been derived three separate harvesting operations, reaping, threshing and winnowing. Reaping, threshing and winnowing are the combination of one single process. The crops which can be harvested with the help of combine harvester are wheat, sorghum, soybean, flaxseed, sunflower where it can separate a straw and the left can lying on the field which can comprise with the stems for any remaining leaves of the crop. Combine harvester is one of the very economics labour saving invention which has significantly reduce the fraction of the population engaged in agriculture.

Mower

Mower is the person or machine that cuts grass or other plants which can grow on the ground a moving is distinguished from reaping which uses a similar implement but traditionally the term for harvesting grain crops.

Rice Huller

Rice huller or rice husker is the agricultural tool which can be used to automate the process of removing of chaff or husk of grain from rice. There are a number of techniques related to the healing rice traditionally it was found that Mortar and pastel, it was there but now a day this is being developed to hull and polished rice.

Winnowing

Winnow is one of the agricultural methods which have been developed by ancient cultures for separating grains from the chaff. It can be used to remove dust from stored grain also. Winnowing is following threshing in grain preparation. In very simple terms winnowing was throwing the mixture into the air so the wind blows away the light chaff, while the heavier grain can fallback down for recovery. This technique involves a winnowing fan or it uses a tool and makes pile of harvested grain.

Milking Machines

There is a device which is also part of farm machinery which is milking machines, which can be used for harvesting milk from cows when manual milking becomes inefficient or it is more labour intensive. One of the models was patented in 1907 of a milking machine for removal of milk from the udder.

Tillage Operations

Tillage operations- Tillage is the process of soil preparation with the pulverization of the soil through mechanical devices. The process is furrowing, digging, cultivating, overturning, and stirring. There are some human-powered and draft animal-powered or mechanized tilling methods. Human-powered tilling methods are with the tools such as shoveling, picking, spade, and hoeing. The draft animal-powered work consists of ploughing, harrowing, cultivating with cultivator shanks, rolling with cultipackers, etc. tillage is classified as primary tillage and secondary tillage. Primary tillage is more superficial such as ploughing to finish rough surface, while secondary tillage is more selective of location such as tillage practices for more refined and smoother surface finish. Secondary tillage is mainly required to prepare the smooth finished seedbeds for the crops. There are some practices that combine primary and secondary tillage such as harrowing and rototilling. The term tillage has another connotative meaning, that is the tilled land. Likewise, the word cultivation also symbolizes tillage sometimes. But in agriculture, tillage, and cultivation both the terms are with the soil agitation, where soil disturbance is done.

Conservation Tillage

Conservation tillage leaves at least 30% of crop residue on the soil surface, or at least 1,100 kg/ha of small grain residue on the surface during the critical soil erosion period. This slows water movement, which reduces the amount of soil erosion. Additionally, conservation tillage has been found to benefit predatory arthropods that can enhance pest control. Conservation tillage also benefits farmers by reducing fuel consumption and soil compaction. By reducing the number of times the farmer travels over the field, farmers realize significant savings in fuel and labor. However, conservation tillage delays warming of the soil due to the reduction of dark earth exposure to the warmth of the spring sun, thus delaying the planting of the next year's spring crop of corn.

Conservation tillage incorporated no culturing, strip culturing, mulch culturing, rotational culturing and Ridge culturing.

- In case of no tillage never use a plough or disc ever again means the aim is for 100% ground cover.
- Strip tillage in this case the narrow strips are still where seed will be planted leaving the soil in between the rows untilled.
- Mulch tillage in this case the soil is covered with mulch to conserve heat and moisture so there is 100% soil disturbance.
- Rotational tillage includes the tillage the soil every 2 years are less often.

Primary and Secondary Tillage

Primary tillage is usually conducted after the last harvest, when the soil is wet enough to allow ploughing but also allows good traction. Some soil types can be ploughed dry. The objective of primary tillage is to attain a reasonable depth of soft soil, incorporate crop residues, kill weeds and to aerate the soil. Secondary tillage is any subsequent tillage, in order to incorporate fertilizers, reduces the soil to a finer tilth, level the surface, or control weeds.

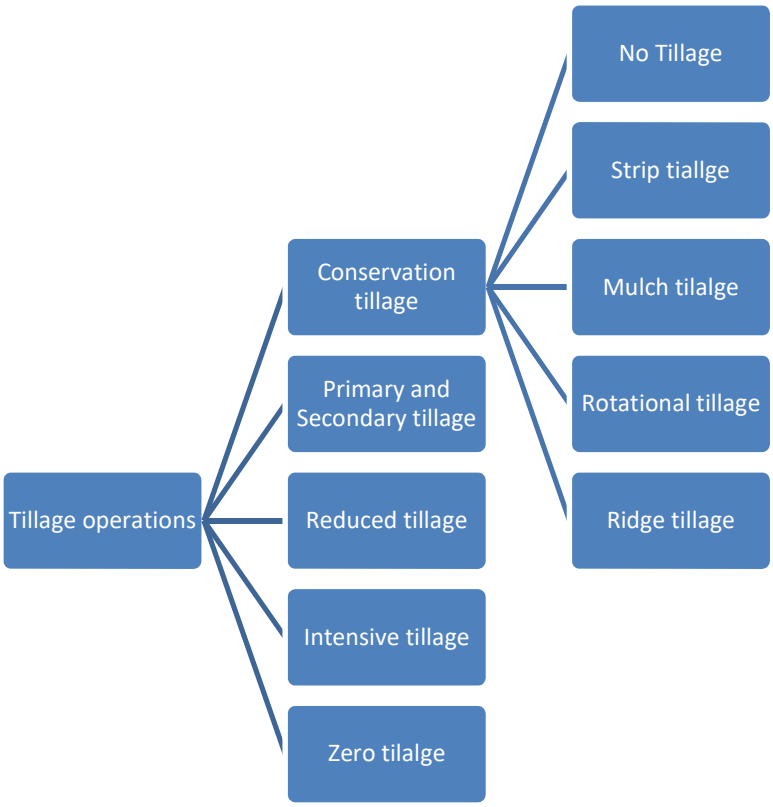


Fig 4.10 Tillage operations

Reduced Tillage

Reduced tillage leaves between 15 to 30% crop residues which cover on the soil or 1000 kilogram per hectare per acre small green residue in the critical erosion period. It can involve the use of the chisel plough, a field cultivator or any other implements.

Intensive Tillage

Intensive tillage leaves less than 15% crop residue which cover 560 kilogram per hectare of a small grain residue that is referred as a conventional tillage but it as a conservation tillage it is now more widely used. This is sometimes not very appropriate to refer this type of tillage as conventional with intensive tillage can involve multiple operations with implements like a mould board disc or chisel plough.

Zero Tillage

Zero tillage is also called as no till. Zero tillage is an extreme form of minimum tillage. Primary tillage is completely avoided and secondary tillage is restricted to seedbed preparation in the row zone only. No-Till farming is one method of practicing zero tillage. The machinery accomplishes four tasks in one operation: clean a narrow strip over the crop row, open the soil for seed insertion, place the seed and cover the seed properly. A wide sweep and trash bars clear a strip over the previous crop row and planter-shoe opens a narrow strip into which seeds are planted and covered.

Impact of Tillage

There are various impacts of tillage, some impacts are positive and some impacts are negative. The positive impact of tillage

- Tillage operations help to lose in an area's top layer of soil or horizon A which is a good symbol for the plantation of crop.
- With the help of mixed harvest residue, organic matter or humus and nutrients can be evenly distributed within the soil because mechanical it can destroy weeds.
- In the autumn tillage is helpful to expose soil crumble overwinter through frosting and defrosting which can help to prepare a smooth surface for spring planting.

The negative impact of tillage:

- It dries soil before the seeding and soil loses nutrients and its ability to store water.
- It can reduce the water infiltration rate of soil as well as it can induce soil erosion by disclosing the cohesive less of the soil particles which can induce erosion.
- Chemical runoff and reduction of organic matter in soil as well as microbes.
- Tillage affects and destroys the soil aggregates as it creates the soil compaction which is called as a tillage pan.
- Eutrophication is the process which may be responsible for nutrient runoff into a body of water.

Tillage Implements

There are various implements it can be categorized into several groups on the basis of its purpose such as primary tillage implements, wooden plough or indigenous plough, soil turning plough, mouldboard plough, one way or reversible plough. There is some special plough also such as subsoil plough, chisel plough, ridge plough, rotary plough and basin lister. Secondary tillage implements are like tractor drawn cultivator, sweep cultivator, harrow disc, harrow blade, harrow indigenous blade, harrow plank and roller.

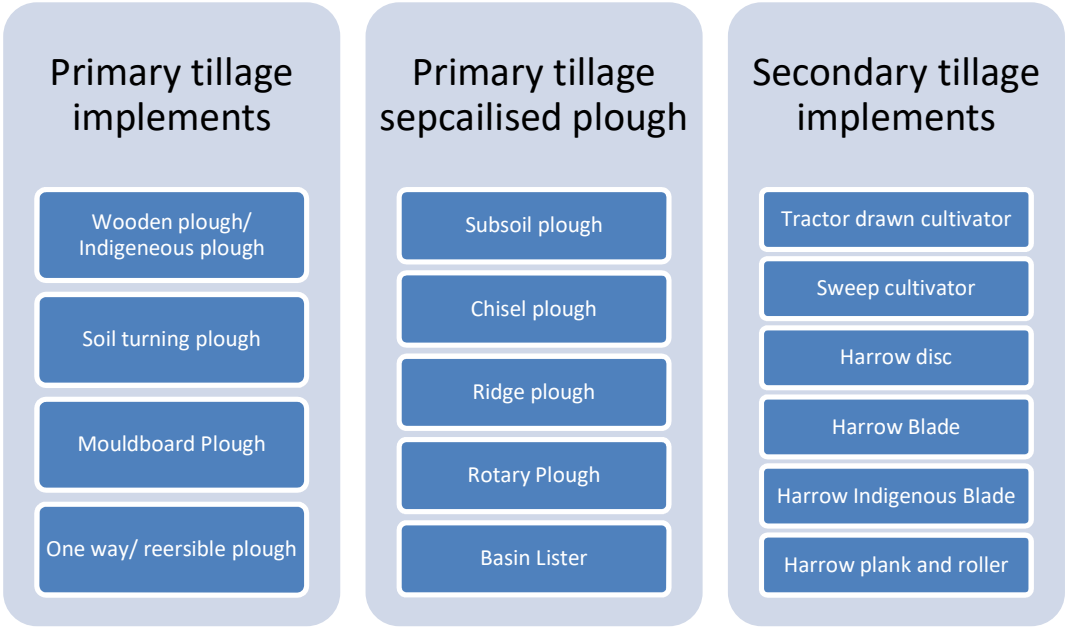


Fig 4.11 Tillage implements

- Primary tillage implements can be utilized for opening and shutting of the soil which is known as clod. These are of three types: wooden plough, iron plough and specific purpose plough.
- Wooden plough or indigenous plough is made of wood with an iron share point which was drawn by bullocks. It cuts a V shaped furrow and opens the soil but there is no inversion.

- Soil turning plough is the instruments which are made of iron and drawn by a couple of bullocks or two relying upon the kind of soil which can be drawn by the work vehicle too.
- Mouldboard plough is the plough with the wing share avalanche interfacing bar, section and handle that leaves no unploughed land as the wrinkle cut will be sliced exceptionally perfect and transformed aside coming about is better pounding.
- Disc plough is the plough which bears little similarity in the basic mouldboard plough which is appropriate for land. It cuts, turns and in some cases breaks furrow slices by means of separately mounted large steel discs.
- One Way Or reversible plough- All the discs of the plough at the same vertical angle, so it is called one way plough. Reversible plough has two mould board ploughs mounted back to back, one turning right, one turning left.

Special Plough

- Subsoil plough is designed to break up hard layers or pans without bringing them to the surface. The body of the subsoil plough is wedge shaped and narrow while the share is wide so as to shatter the hard pan and making only a slot on the top layers.

- Chisel plough is used for breaking hard pans and for deep ploughing (60-70 cm) with fewer disturbances to the top layers. Its body is thin with replaceable cutting edge so as to have minimum disturbance to the top layers. It contains a replaceable share to shatter the lower layers.

- Ridge plough has two mould boards, one for turning the soil to the right and another to the left. The share is common for both the mould boards i.e. double winged. These mould boards are mounted on a common body. The, ridge plough is used to split the field into ridges and furrows and for earthing up of crops.

- Rotary plough cuts the soil and pulverizes it. The cutting of soil is done by either blades or tynes. The blade types are widely used. The depth of cut is up to 12 to 15 cm. It is suitable for light soils.

- Basin lister is a heavy implement with one or two mouldboards or shovels. These shovels are mounted on a special type of frame on which they act alternately. This implement is used to form listed furrows (broken furrows with small dams and basins) to prevent free runoff of rainfall and blowing off the soil in low rainfall areas.

Secondary Tillage Implements

There are various types of implements, for example, cultivator, harrow, planks, roller that can be utilized for the secondary tillage.

- Cultivator is an implement used for finer operations like breaking clods and working the soil to a fine tilth in the preparation of seedbed. Cultivator is also known as tiller or tooth harrow. It is used to further loosen the previously ploughed land before sowing. It is also used to destroy weeds that germinate after ploughing. Cultivator has two rows of tynes attached to its frame in staggered form. The main object of providing two rows and staggering the position of tynes is to provide clearance between tynes so that clods and plant residues can freely pass through without blocking. Provision is also made in the frame by drilling holes so that tynes can be set

close or apart as desirect. The number of tynes ranges from 7 to 13. The shares of the tynes can be replaced when they are worn out.

- In stubble-mulch farming, it is difficult to prepare the land with ordinary implements due to clogging. Sweep cultivator is the implements useful under this condition. It consists of large inverted V shaped blades attached to a cultivator frame. These blades run parallel to soil surface at a depth of 10 to IS cm. They are armged in two rows and staggered. Sweep cultivator is used to cut up to 12 to 15cm depth of soil during first operation after harvest and shallower during subsequent operations. It is worked frequently to control weeds. It can also be used for harvesting groundnut.

Implements for Sowing

There are certain farm machineries which can have a separate purpose for sowing like ploughing, seed drill, ferti cum seed drill, and mechanical seed drill. These are the equipment, which can be used for the Sowing process.

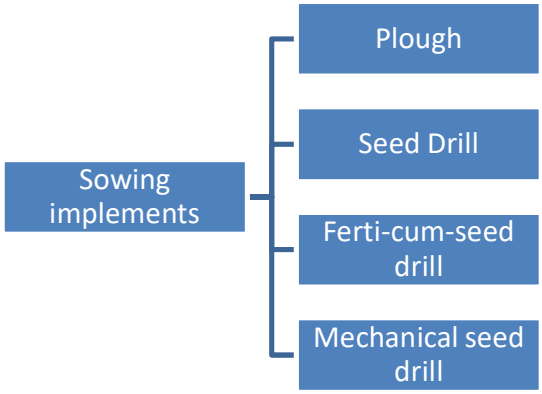


Fig 4.12 Sowing Implements

- Plough- seeds are dropped by hand in the furrow formed by the country plough.
- Seed drill- it includes a wooden beam
- Ferti-cum-Seed Drill- In that case fertilizers can be placed at the depth of 5 cm and 5 cm away from seed grows at effective utilization of fertilizer.
- Mechanical seed drill- In this case in both the operations the drilling seed and fertilizers can be done simultaneously by ferti cum seed drill so it was quite similar to the seed drill but there are some extra times and Hopper of drilling fertilizer.

Implements for Cultivation

There are certain implements which can use for the cultivation purpose also like wooden plough, small blade harrow and weeders.

- Country plough and ridge ploughs are used for earthing sugarcane, potato etc. Country plough is run to a shallow depth to control weeds in widely spaced crops and fruit trees.

- Small sized blade harrows are widely used for intercultivation. Several of them are designed by local artisans to suit special purposes and are given local names. These are simple in design, easy to make, cheap and serve the purpose excellently.
- Tobacco blade harrow has longer blade than its beam so as to scrape the weeds on the soil without damaging the brittle petioles of tobacco.
- Star weeder is one of the gear which pushed by difficult work that comprises in long wooden and iron vertical bar with a little even bar holding the implement. It is very helpful to control little weeds in close developing yields like groundnut, foxtail millet.

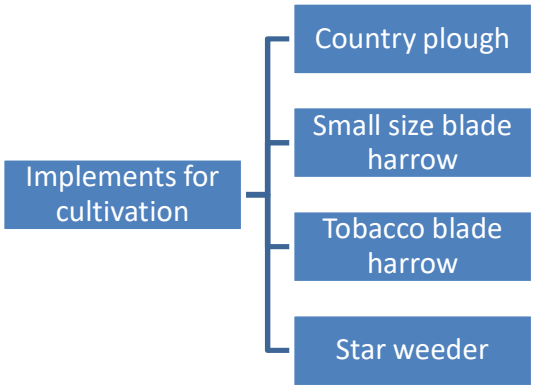


Fig 4.13 Implements for cultivation

To Do Activity

- Discuss the transformation brought in agriculture due to farm mechanization.
- Differentiate the primary tillage implements and secondary tillage implements in terms of consequences of seed bed preparation.

4.5 Seed Technology

Seed Technology

Cowan (1973) has recognize Seed innovation as a control of study which have to do with seed creation, upkeep quality and conservation. Seed innovation can be characterized as the technique wherein the hereditary and physical attributes of seed can be improved which can include the exercises, recommend assortment advancement, assessment and delivery handling, seed creation, stockpiling and affirmation. Seed innovation is interdisciplinary science which included expansive scope of subjects, for example, it incorporates the advancement of unrivaled yield assortments their assessment and delivery seed affirmation, seed quality control, seed showcasing and circulation, seed physiology, seed creation and seed dealing with dependent on present day plant and rural sciences.

The qualification among seed and grain is imperative being of fundamental significance to farming a state can be carefully called as an undeveloped organism and living being which inserted in a supporting all the food stockpiling tissues. The deductively created seeds can be unrivaled as far as seed quality, in

particular, improved assortment, varietal immaculateness opportunity for blends, treatment of seeds and safe dampness content and so on.

Role of Seed Technology

There are various roles of improve seed on the basis of Feistritzer (1975).

- Improve seed can be a career of new technologies it can introduce the quality seed of a new variety wisely which combine with other input significantly in which increasing the yield.
- An improved seed can be an essential apparatus for a protected Food Supply where the exceptionally assortment program in India has given A Remarkable increment access creation and food imports from different nations regardless of having a fast development in the number of inhabitants in the nation.
- Improved seeds can be the chief way to make sure about harvest in is less ideal territory of creation on the grounds that the flexibly of good quality seed is improving assortment and the appropriate to those zones where it is having a solid or significant commitment to make sure about higher yield.
- Improve seeds can be a mode for quick restoration of agribusiness if there should arise an occurrence of catastrophic event if there should be an occurrence of flood and dry season influenced zone the legislature can give the improve seed from National seed stock to restore the farming creation.

Seed Classification

Based on the nature of seed it may be sorted into different classes so condition of informed assortment can be increased into four level framework by association of ICAR establishments. These are nucleus seed, breeder seeds, Foundation seed and certified seed.

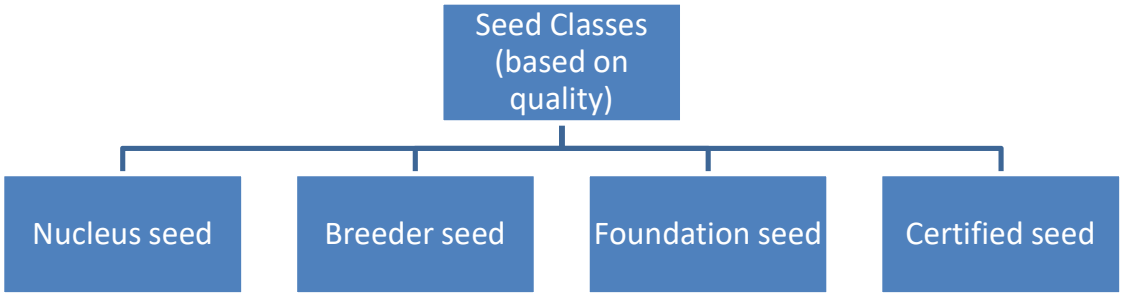


Fig 4.14 Seed classification (ICAR)

- Nuclear seed: This is the hundred percent genetically pure seed with physical purity and produced by the original breeder/Institute /State Agriculture University (SAU) from basic nucleus seed stock. A pedigree certificate is issued by the producing breeder.
- Breeder seed : The progeny of nucleus seed multiplied in large area as per indent of Department of Agriculture and Cooperation (DOAC), Ministry of Agriculture, Government of India, under supervision of plant breeder / institute / SAUs and monitored by a committee consisting of the representatives of state seed certification agency, national / state seed corporations, ICAR nominee and concerned breeder. This is also hundred percent physical and genetic pure seed for production of foundation seed. A golden yellow colour certificate is issued for this category of seed by the producing breeder.

- Foundation seed: The progeny of breeder seed produced by recognized seed producing agencies in public and private sector, under supervision of seed certification agencies in such a way that its quality is maintained according to prescribed field ad seed standards. A white colour certificate is issued for foundation seed by seed certification agencies.
- Certified seed: The progeny of foundation seed produced by registered seed growers under supervision of seed certification agencies to maintain the seed quality as per minimum seed certification standards. A blue colour certificate is issued by seed certification agency for this category of seed. The foundation and certified seeds can be multiplied at stage 1 and 2, but the reproduction cannot exceed three generations after breeder seed.

According to Thompson (1979), received quality can be decided as multiple concepts is comprise several component and its relative importance in the different circumstances. Basically, it has put emphasis on analytical purity, species purity, freedom from leaves, germination percentage, seed vigour and health, seed moisture content and seed size, weight and specific gravity, seed quality characteristics.

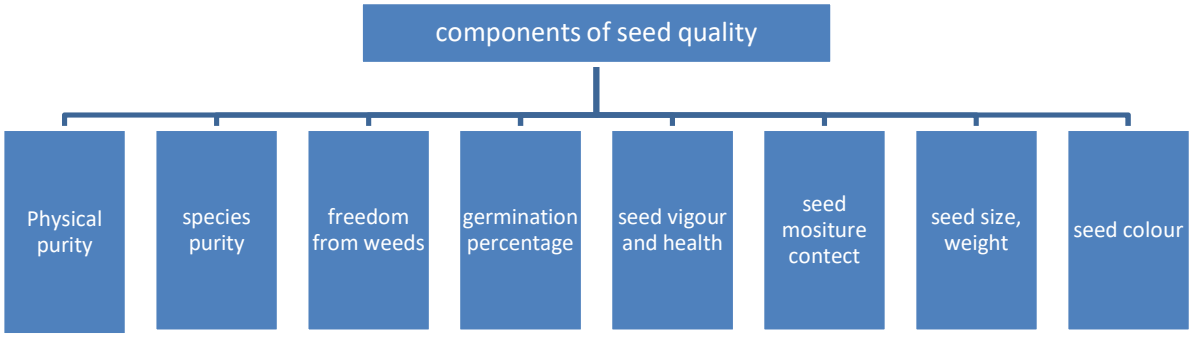


Fig 4.15 Components of seed quality

Box 2.4 Characteristics of good quality seed

- Higher genetically purity:
  - Breeder /Nucleus - 100%
  - Foundation seed - 99.5%
  - Certified seed - 99.0%
- Higher physical purity for certification
  - Maize , Bhendi - 99%
  - All crops (most) - 98%
  - Carrot - 95%
  - Sesame, soybean & jute - 97 %
  - Ground nut - 96 %
- Possession of good shape, size, colour, etc., according to specifications of variety
- Higher physical soundness and weight
- Higher germination (90 to 35 % depending on the crop)
- Higher physiological vigour and stamina
- Higher storage capacity
- Free from other crop seeds (Expressed in number /kg) - Other crop seeds are the plants of cultivated crops found in the seed field and whose seed are so similar to crop seed that is difficult to separate them economically by mechanical means. Eg. Mixtures of Wheat, oats seeds in barley.
- It should be free from objectionable weed seeds -These are plants of weed species which

are harmful in one or more of the following ways.
    - The size and shape of their seeds are so similar to that of the crop seed that is difficult to remove their seed economically by mechanical means.
    - Their growth habit is detrimental to the growing seed crop due to competing effect.
    - Their plant parts are poisonous or injurious to human and animal beings
    - They serve as alternate hosts for crop pests and diseases.
- It should be free from designated diseases - It refers to the diseases specified for the certification of seeds and for which certification standards are to be met with . These diseases would cause contamination, when they are present in the seed field or with in the specified isolation distance (eg. loose smut of wheat). For this the the certification distance has been prescribed as 180 meters.
- It should have optimum moisture content for storage - Long term storage - 6 - 8 % , Short term storage - 10 - 13%
- It should have high market value.

Source: https://vikaspedia.in/ /agriculture/agri-inputs/seeds/seed-quality

Breeder Seed Maintenance

Breeder seed requires certain conditions to maintain its quality, the breeder seed stock can obtain from nucleus seed. The consideration should be paid on

- Land necessity
- Isolation
- Roughing
- Field assessment
- Harvesting and drying
- Sorting

Seed Certification Process

Seed certification process can be voluntary, but sometimes government gives certification for the variety of seeds. There are six steps included in the seed certification. These are as follows:

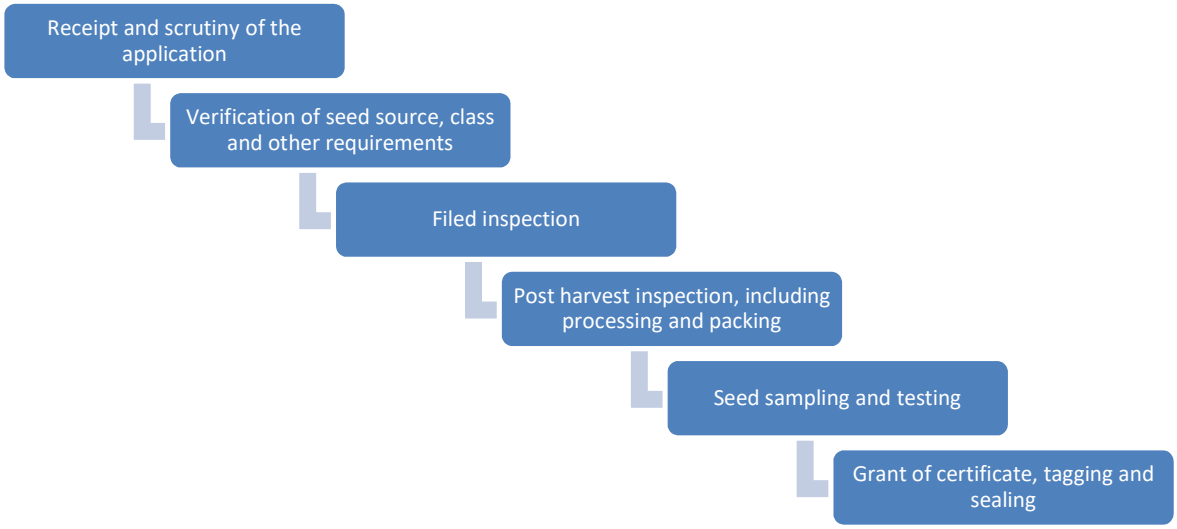


Fig 4.16 Seed certification process

Seed Drying

Seed drying is the cycle to decrease the dirt dampness substance to make spare the seed, which is significant so as to keep up the seed suitability and whether it else it can influence to fall apart. There are different focal points of seed drying are there, similar to it allows early gather, so that the arranged and labor can be utilized adequately it license long haul stockpiling and upkeep the seed quality.

There are different techniques for seed drying these are

- sun drying and
- Forced air drying.

Sun drying technique where dampness of seed can be delivered in the field before reaping and later by sun drying on the sifting floor. The framework incorporates gathering of yields when they are completely dried in the field in leaving the collect repeat in the field for specific days for sun drying is there. Advantage of this method of sunrise there is no additional expenditure as special requirement for that, while the disadvantage is that it takes lot of time and it's supposed there are delayed in the harvesting and risk of that can damage and increase possibility of mechanical admixtures. There are certain precautions should be taken in sun drying like donot get spread the product on the wet, dirty or kachcha threshing floor. Only one proprietor ought to be dealt with at once and care ought to be taken to maintain a strategic distance from mechanical blends. Constrained air drawing framework is the place the common air is constrained into the seed and the air going through moist seeds get the water the dissipation causes the air in the seed.

Seed Storage

There is certainly unique equipment which required for make due as practical regenerative creatures and the time and spot are directly for the start of another age. Based on life span of seed during the capacity it very well may be isolated into two, conventional seeds and Recalcitrant seeds.

- Orthodox seeds are long live seeds which can be effectively dried in the dampness content as low as 5% without injury without injury and these can endure frigid temperatures so at physiological development that contained in the standard seeds are 30 to half.
- Recalcitrant seeds are fleeting seeds which can't dried the dampness content beneath 30% without harming and unfit to endure freezing. The seed are from perpetual trees in sodden jungles, for example, coconut, espresso, citrus the seeds develop and exist in the leafy foods secured with garish or succulent ariloid layers and testa.

The principles related to seed storage are

- Storage condition should be dry and cool
- Control of insect pest
- Sanitation needed in the seed stores
- Before putting seeds into capacity, it should be dried to safe dampness limits
- Store just excellent seeds, which is very much cleaned, treated and with high germination and power.

Seed Testing

Seed testing needed to check the nature of seeds on different ascribes, for example, dampness substance, germination and life, physical and hereditary virtue, opportunity from seed borne illnesses and bug invasion. There are different targets of seed testing. These are

- Quality for appropriateness of planting
- To check the seed quality issue and its causes
- Need for drying and preparing and explicit methodology which can be utilized.
- Check the quality principles

Provide basis for consumer discrimination in the market among seeds lots.

To Do Activity

- Differentiate the seed classes in terms of its utilization and commercial purpose.
- Experiment to examine the seed quality on the basis of various factors required into consideration for seed quality.

References

- Agrawal, R.L.(1980). Seed technology. Oxford and IBH Publishing Co Pvt, Ltd, New Delhi
- Balasubramaniyan P and SP. Palaniappan (2002). Principles and Practices of Agronomy. Agrobios (India), Jodhpur.
- Chaterjee B.N. and S.Maiti, (1993). *Cropping system – Theory and practice*, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Chatterjee, B.N. and Matti, S. (1984) Cropping System-Theory and Practice. Oxford and IBH Publishing co, Calcutta
- Chidda Singh, (1997). *Modern techniques of raising field crops*, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Gopal Chandra De, (1997). *Fundamentals of Agronomy*, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Gupta U.S., (1995). *Production and improvement of crops for drylands*, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi
- ICAR, (1996). Handbook of Agriculture, Indian Council of Agricultural Research, New Delhi.
- Nakra, C.P. (1980). Farm Machinery and Equipment. Dhanpati rai and Sons, Delhi
- Palaniappan S.P., (1985). *Cropping systems in the Tropics – Principles and Management*, Wiley Eastern Limited and Tamil Nadu Agricultural University, Coimbatore.
- Palaniappan, S.P (1985). Cropping System in the Tropics- Principles and Management. Wiley Eastern Ltd, New Delhi and Tamil Nadu Agricultural University. Coimbatore
- Seed Quality — Vikaspedia, TNAU agritech portal, retrieved from https://vikaspedia.in//agriculture/agri-inputs/seeds/seed-quality
- TNAU, (2003). *Crop Production Guide*, TNAU and Directorate of Agriculture, Chennai.
- Unger, P.W and McCalla, T.M. (1980). Conservation tillage. Advance Agronomy.33:2-58
- Yellamananda Reddy T. and G.H. Sankara Reddi, (1997). Principles of Agronomy. Kalyani Publishers, New Delhi

Model Questions

1. Differentiate among the major crops season in India in terms of climatic conditions and intercultural practices.
2. Explain the cropping system in India, with particular crop specific cropping system.
3. Discuss the most efficient cropping system and cropping pattern in India
4. Explain the post cultivation practices by providing suitable example under propping, topping and desuckering.
5. What is the effect of farm machineries on agricultural practices and yield?
6. Discuss the relevance of primary tillage operations and secondary tillage operations.
7. Differentiate the farm implements required for sowing and cultivation.
8. Explain the components of seed quality check.
9. What are the seed certification process?

Chapter 5 Modern Agriculture

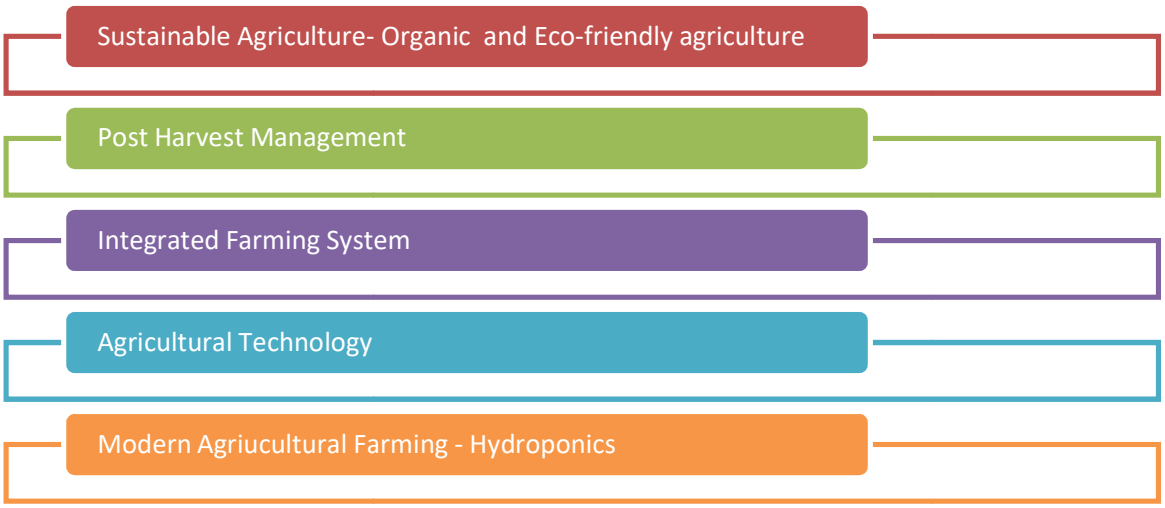
Introduction

Agriculture means the practice of farming in a sustainable manner which meets the food requirement of the society present without compromising the future generation's requirement with the understanding of the current biological system of management. There are different techniques to build the manageability of agribusiness. In horticulture there are huge natural impressions that assume a noteworthy function in causing environmental change, water shortage, deforestation land corruption and other ecological effects. Maintainable agribusiness is probably the most ideal approach to alleviate the environmental change which can make manageable food framework. It depends on the feasible horticulture that gives a potential arrangement and so farming framework can have the option to proficient just as without having a lot of effect on the ecological conditions. Post-gather the board includes different sorts of medicines for newly reaped items plant produces goes through different medicines to limit the misfortunes and increment its time span of usability and enhance the item. The different productive methods, for example, gathering, transportation, dealing with, capacity, handling, conservation and bundling for the piece of post-harvest management. Weather aberrations may include drought and flood type of situation. Drought can be defined in various ways like the condition where the crop can fail to make sure the cause of the difficult supply of water in the rainy season even after there are rains.

Objectives

- To explain sustainable agricultural practices.
- To explain various post-harvest management.
- To describe integrated farming system in the current agricultural scenario.
- To examine the agricultural technology in the context of weather aberration and weather modification.
- To explain the hydroponic and modern agricultural farming practices.

Chapter Structure



5.1 Sustainable Agriculture- Organic and Eco-friendly agriculture

Sustainable Agriculture

Sustainable food system means the system where it doesn't require much chemicals to conserve the energy and water and it emphasizes the local production with decreasing cost of production and inputs. This means there is a proper utilisation of resources in an efficient manner. In order to make agriculture sustainable, some important principles need to be incorporated which are:

- It is required to consider the need of the people and to provide the nutrient rich food to the farmers.
- The different farming communities which can help them to maintain their health as well as improving the quality of life.
- It is required to consider the profit when there farming.

The consideration of earth and atmosphere is important because the farming practices must be ecologically sound and promote healthy biodiversity with a practical management of natural resources.

Profits of Sustainable Agriculture

Sustainable agriculture is important because it encompasses a wide range of production practices. It includes the conventional as well as organic practices where the regional integrated system of plant and animal has been designed in the manner that can produce for a long term.

- Production should be sufficient for the human beings for food, fodder and fuel in proportion to the rising population.
- There should be proper concern to environment and expansion of natural resource supply.
- There should be sustainable economic viability of agricultural system.

There are many benefits of sustainable agriculture from the environmental point of view. It is not like intensive agriculture because there is a possibility for benefit to the environment as well as preserving the natural resources. Sustainable agriculture can help environment like recycling nutrients and water. By decreasing the rural overflow, forestalling contamination of lakes and waterways, sparing water, keeping soil fertility, by upgrading carbon sequestration by soil and enduring vegetation by advancing productivity of farm activities.

The well-being is closely related to sustainable agricultural practices because it is producing safe food with the high traditional values where the nature of food is a priority. There are a number of studies that discovered the dietary substance of grain and organic products with vegetables. Experimentally it has been demonstrated that high yielding harvests have less limit of retaining supplements from the soil in view of their root frameworks which can result in lower healthy substance.

Along with that, there is a negative impact of the increasing use of pesticides on the food products which has made changes in the nutritional composition of food. In the case of sustainable agriculture, it is suggested to take no chemicals for the growth of food. Crop diversity is one of the important points is the cultivation of local varieties. There are preferences of the manageable cultivating practices as far as giving monetary chances to the regional networks like giving openings for work and it assists with supporting the social financial advancement of rural region. Alongside that, the economical food creation is better versatile to climatic change and it assists with reinforcing environment strength. These attributes are indicated more significantly for building a fruitful food creation framework as far as giving monetary chances to the regional networks like giving openings for work and it assists with supporting the social financial advancement of rural region. Economical food production is responsive to climatic change and it assists with reinforcing environment strength. These attributes are indicated more significantly for building a fruitful food production framework which can face the future.

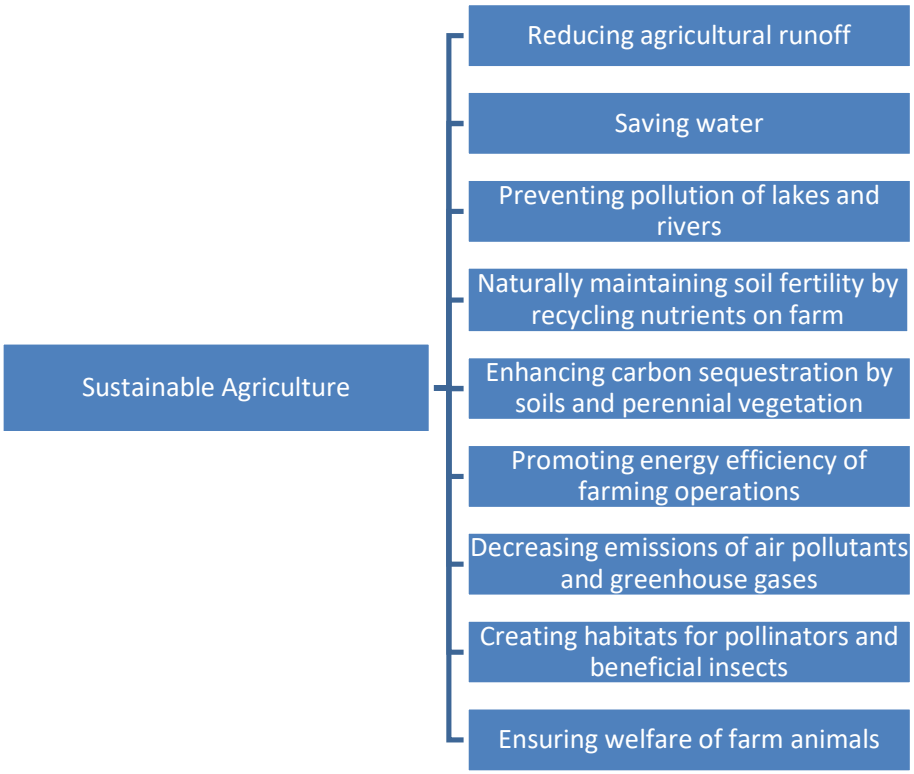


Fig. 5.1 Profits of Sustainable Agriculture

Factors Affecting Sustainability

There are many practices which cause a long-term damage to the soil included excessive tillage practices of the soil that lead erosion and irrigation without adequate drainage system where the salinization process happens. Important factors for farming are climate, soil, nutrients and water resources. Out of them soil and water conservation are utmost significant factors with regard to the human intervention. At the time of production and harvesting of the crops, there are some minerals which can be removed from the soil and without replenishment the land suffers from the nutrient deficiency which affects crop yields. Sustainable agriculture depends on replenishing the soil with the non-renewable resources such as natural gas or mineral ores.

Sustainable Agricultural Practices

In agriculture experiments have been done to make it sustainable which may include crop rotation, crop diversification, etc.

- Crop diversification practices include intercropping or growing of mixed crops in the same area.
- There are various shelter crops such as clover or hairy vetch which can be imbedded in the off-season sometimes where the soil cannot be left bare. The cover crops can help and protect the soil health by preventing erosion and provides soil nutrients and replenishes as well as reduces the use of herbicides.
- Falling or eradicating tillage thwarts the weed control. There is either no tillage method or reduced tillage method that involves inserting seed directly into the undisturbed soil which can reduce the soil erosion.

- Application of integrated pest management has several methods including mechanical/ biological control which can be applied systematically to keep the pest population under control with the minimum utilisation of chemical pesticides.

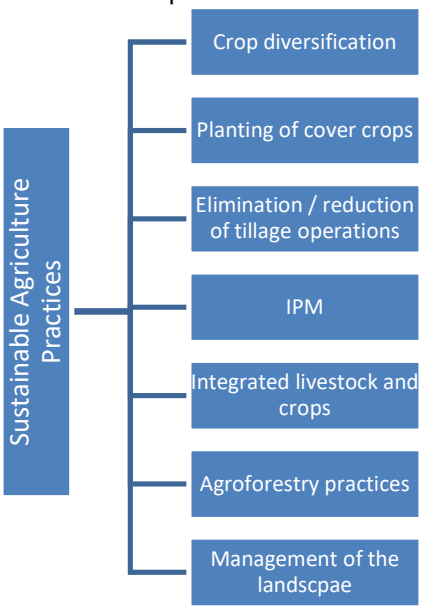


Fig. 5.2 Sustainable agricultural practices

- Integrated domesticated animals and yield where the mechanical farming will in general keep plant and animal production separate with animals living a long way from the territory where their field is delivered and harvests can develop in the better place with the assistance of plentiful manual composts.
- By blending the trees or bushes farmers can give shade and shelter to the plants and protect animal and water resources which can provide additional income.
- Management of the landscape increases the value of land by putting certain checks. Along with that it can control soil erosion, reduce nutrient run off and help pollinators to increase the biodiversity.

Sustainable Farming Methods and Practices

They do not have to be organic but there are many more methods to make it more sustainable. Different practices may have some overlapping but it may be fully or partially organic. They are called permaculture, biodynamic farming, hydroponics and aquaponics, urban agriculture, agroforestry, food forest polyculture, etc.

- Permaculture applies natural rules to the advancement of human settlement which permits humankind to live amicability with on regular world. The standards of permaculture in morals can be applied in different zones of living and additionally which can incorporate the nearby economy, vitality framework, water, lodging framework and food creation. Primarily to deliver food through permaculture is an expectation plan.
- Biodynamic cultivation joins biological and wholistic drawing which depends on the way of thinking of anthroposophy. Farmers can be urged to deal with their homestead as one living being place of developed species. Biodiversity of plants, creatures and gainful microbes is one of

the mainstays of biodynamics and the objective is to make a tough biological system for the advantage of all the living life forms.

- Hydroponics and Aquaponics are imaginative cultivating methods which include the development of plants without soil to support them into the water. Aquaculture framework harvests can be developed without the roots in the manual arrangements in the rocks or perlites. Hydroponics framework joins the raising of amphibian creatures, for example, fish with the development of aquaculture crops. In hydroponics framework, water can contain squander material likewise from the hydroponics fish which can be used to feed the aqua-farming plants.
- Urban farming develops food nearer home involving urban communities in parts of the globe and so there are opportunities for metropolitan agribusiness. There can be terrace farms and gardens, and metropolitan nurseries, indoor aqua-farming, etc.

To Do Activity

- Discuss the conventional farming practices of your locality and make plans to make the existing farming practice sustainable.

- Agroforestry and food forests include the development of trees and bushes among the harvests and connecting areas. Agroforestry framework can join farming and steward service practice which can make it beneficial and different land use should be possible in an economical way. Trees can make a good microclimate which keeps up an ideal temperature and soil dampness. They can also protect from the wind and heavy rains and improve the soil structure. Agroforestry can be a boon for farmers in dry districts where soil is susceptible to desertification.
- Polyculture and crop rotation attempt to impersonate common guidelines to accomplish the best outcome. Polyculture means development of harvest species for one zone and tends to create more varieties of items from one plot to use the accessible assets. As the biodiversity will be high, it can make the framework stronger to face climate changes.
- Natural pest management in one for increasing sustainability the environment only but also for nutritional feed.
- Natural pest management prevents the use of synthetic and other chemicals. Application of more chemicals is not a long-term solution. Farmers look for long-term solutions.
- Mulching and other methods are used for sustainable agriculture.

5.2 Post-Harvest Management

It includes processes which can be done immediately after harvesting and which may include training, cleaning, arranging and pressing.

- For instance, in upper Himalayas various harvests can be developed which may incorporate grain crops, beats, oilseeds, sugarcane, root yields, vegetables and subtropical organic products like mango, citrus organic products, litchi and grapes.
- Temperate natural products like apple, pear, apricot, peach and nut crops. The strategy for taking care of bundling, stockpiling and groundwork for various products and subsequent consumption depends on the agro-climatic diversity.

Curing of Cereals

There are various methods for it like:

- Maize plant with its stocks is gathered and knotted into packages. Each bundle is collected from a different place and put up in one place. Stalking of maize for 30 to 45 days can ensure lightening and facilitate easy separation of cobs from the husk.

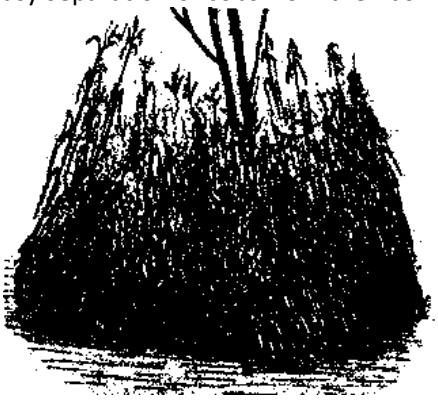


Fig. 5.3 Maize curing by stacking (Thua or Zhumb)

- Paddy is harvested and integrated with a little pack called as pooli or poola. It is kept to dry under open conditions for three-four days and the packs are marked for one spot.
- Millet grains are permitted to age incompletely, then into a warmth and covering the warmth with tarpoline. This method is called Ghardena.

Cleaning of Grains

There are two common methods for it: one is winnowing and another is bulk cleaning of grain.

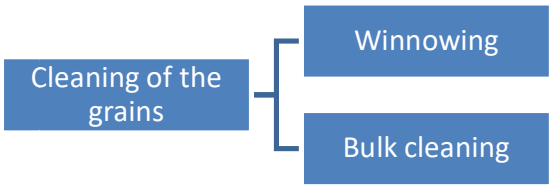


Fig. 5.4 Cleaning of the grains

- Winnowing grains and pulses is done by using a container of tin and grain put in it. Slow winnowing separates sand and husk from the grain. Different kinds of dry grains, for example, wheat, maize, paddy, beats, etc., can be cleaned in this way.

Fig. 5.5 Winnowing of Grains

- Bulk cleaning of grains can be done by using a container made of bamboo stick and the grain is put in it and allowed to fall from a height of four or five feet in the thin vertical flow in the path of cross wind. The grain particle blows away and grains can be separated because they fall on the ground. The use of fan can be accelerator in this cycle of cleaning. This cleaning technique depends on the thickness of the material to be isolated. Utilization of air separators for the grain cleaning depends on this standard.

Fig. 5.6 Cleaning Grains for Separating Husk from Grain

Packaging of Food Commodities

- For packaging of fresh products, various types of containers can be used. In the lower areas of the country the container is made of bamboo which is used for packing potato, ginger, turmeric, etc., for conveying from the field to the house. For pressing clean grain, heartbeats and flour the compartments inside are fixed with cow fertilizer where the stick can pack 25 to 30 kg. material.
- For packaging of short-lived items like tomato, two bamboo boxes can be utilized which are secured with gunny sacks on the top.
- For the bundling of pickles like pickle of mango, they can be pressed in the earthen pots. They are sanitized by utilizing vapor created from consuming red chillies along with a little mustard oil. Then the container is covered with the lid made of wood from the top. The antimicrobial property of fumes of red chillies, mustard oil and asafoetida (heeng) not only keeps the containers fresh but increases the shelf life of the contents.

Storage of Food Commodities

- For storage of food grains like rice, special structure can be made from bamboo. The utilization of bamboo compartments permits a free movement of gases inside the grain and can keep holder on the ground floor which safeguards cool temperature for capacity. Utilization of neem leaves, turmeric and mustard oil can also be done. Grains can be mixed with neem and mint leaves, and stored in the bins.

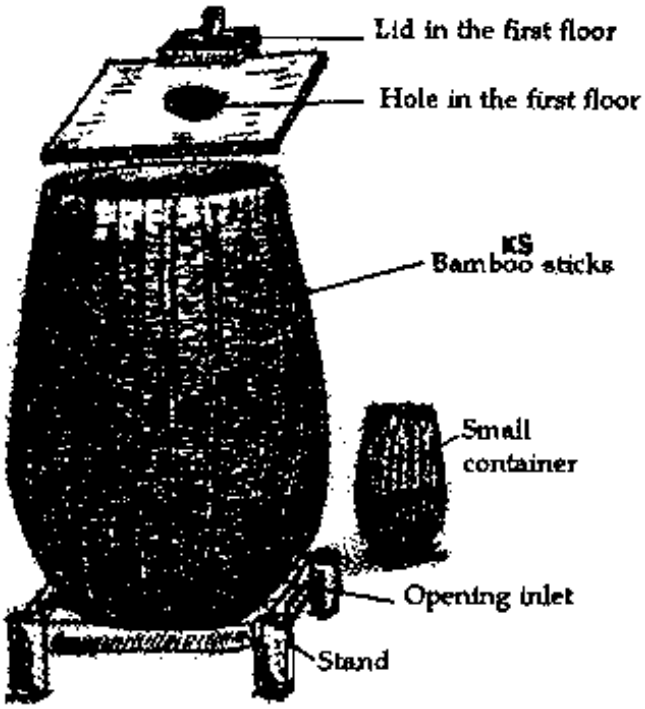


Fig. 5.7 Gram Storage Made of Bamboo

- For the storage of pulses like urad, the grains can be blended with turmeric powder and afterwards put shut compartments.
- The root crops like potato, ginger, turmeric, colocasia, etc., can be stored in underground pits and the top secured with soil.

Degreening

In post-harvest treatment of citrus fruits there is a process called degreening. There are two methods of degreening, one is exposing to ethylene and another is artificial colouring.

To Do Activity

- List the practices for curing of cereal crops in your region.
- Discuss various storage options for cereal crops and pulses in your region.

In the case of post-harvest management the value addition to the food products is considered as a vital step which involves the processes of fruits and vegetables with dual purposes: one is preventing losses which can occur due to the lack of appropriate storage facility and second increasing income due to processing of the commodity. Fruits and vegetables not only provide the growers nutritional security but higher income also. With better production practices and careful harvesting, proper packaging and transportation the produce is of good quality.

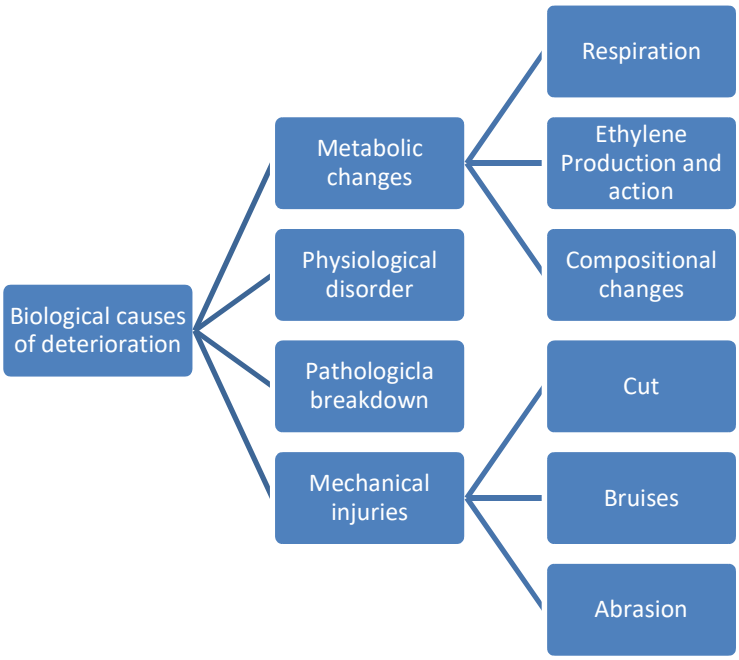


Fig. 5.8 Biological causes of Deterioration of fruits and vegetables

The losses of fruits and vegetables after harvesting may be attributed to:

- Water substance can diminish with time as there is continuation of living cycle inside the produce which results in the product getting wilted or it loses its bloat.
- Vitamin C can diminish with time after reaping.
- Because of cooking water solvent Vitamins B and C may diminish.
- Stripping may cause huge losses in food production as a large portion of the supplement has epidermis skin. For example, potato has protein content which holds fast to the skin.
- In vegetable cooking when water is utilized, it breaks up minerals and minor components.

Role of Post-Harvest Management

There is a regular use of fruits and vegetables every day in the form of salads. But most of us are not aware about how to take their care.

- Fruits and vegetables are fragile products and inclined to wounds or harms, that is, losing appearance and freshness.
- The waste in products can happen due to microbial assault, auto oxidation and creepy crawly bug assault. About 25 to 30% of the leafy foods are lost because of wastage costing around Rs 67000 crores every year. A conservation of just 1% can save Rs 67 crores yearly.
- Leafy foods are mostly short-lived items due to high dampness content, high pace of physiological exercises like breath and maturing, microbial assault, rapid biochemical changes, etc. Gathering period for them is around one to two months. Consequently, some steps are essential:
    - proper dealing with them,
    - packaging at low temperature,
    - maintenance of low temperature during transportation,
    - proper pre- and post-reaping treatment so as to expand the time span of usability, etc.

Post-reaping losses need to be curtailed significantly. Some of the desirable steps which can be taken are:

- packaging,
- transportation,
- storage,
- home protection, etc.

Harvesting

This is a crucial time for the cultivators of fruits and vegetables. Harvesting method is important because faulty harvesting and handling can reduce the market value, leading to rotting.

Post-Harvest Physiology

Natural products are to be reaped at a proper phase of development to maintain their quality. Poor quality and uneven ripening can result in poor shelf life because it may result in:

- generation heat as sugar,
- oxidization of the fat and protein in the cells of the crops,
- loss of flavour,
- lower saleability,
- rapid overall deterioration, etc.

Post- Harvest Handling

Post-harvest handling includes storage, transportation, pathological and entomological factors, etc. In case of storage there are various factors to be considered such as packing temperature, relative humidity, packing sanitation, ethylene evolution and its bad effects during storage.

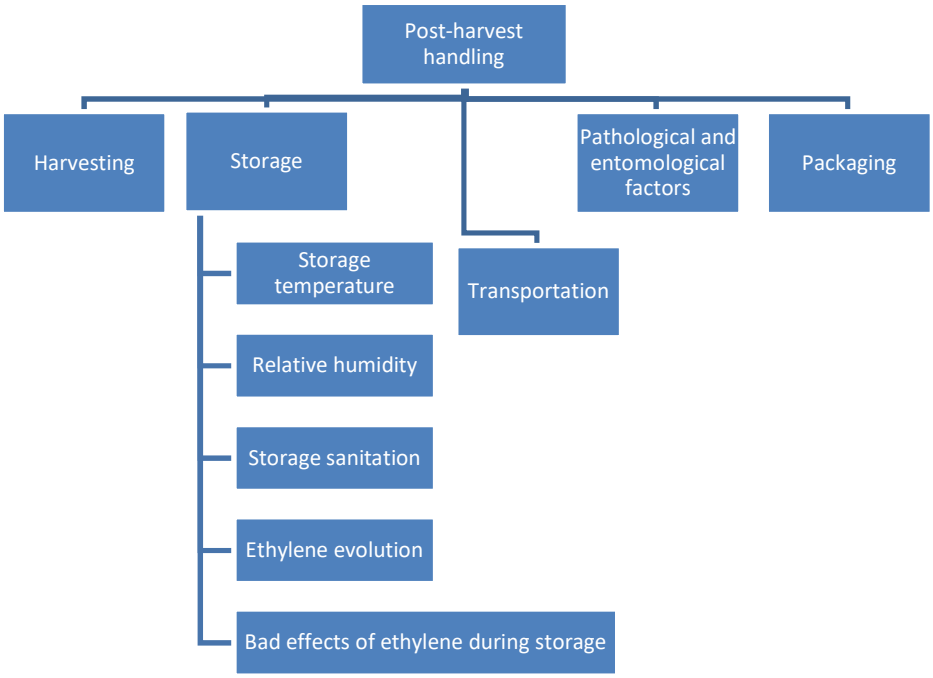


Fig. 5.9 Post-harvest handling

i. Harvesting may be finished during the cool hours like the first part of the day and the produce held under the shade. It is necessary to prevent skin breaks, wounds, spots, decays, rotting, disintegration, etc. Vegetables are susceptible to them because of their tender texture, high

moisture content, etc. Their chances by mechanical damage also increase. Moisture loss can go up to as much 400% by a solo bad shiner on the Apple.

ii. Storage is one of the significant angles if there should arise an occurrence of post-gather treatment of foods grown from the ground where natural products can go waste due to ill-advised storerooms which can do harm:

- textural hues can change,
- unwanted metabolic changes and respiratory seed creation,
- loss of dampness and shrinking,
- undesirable growth such as sprouting in potatoes,
- spoilage by bacterial invasion, etc.

In the case of storage, factors such as temperature, humidity, sanitation and ethylene evolution are important.

Table 5.1 Crops with high and low respiration rates

Crops with high respiration rate	**Crops with low respiration rate**
Cabbage, green onion, snap beans, asparagus, broccoli, mushrooms, peas, sweet corn, etc.	Nuts, apples, grapes, garlic, onions, potatoes, sweet potato, etc.

a. Storage temperature is required to be maintained because there can be chances of damage.
   - Crops such as cucumber, eggplant, pumpkin, sweet potato, etc., are sensitive to the chilling injury.
   - Tropical and subtropical natural products like mango, banana, papaya, pineapple, etc., are touchy to the chilling temperature.
   - There are sure harvests, for example, muskmelon, sweet pepper, winter squash, tomato and watermelon which are moderately sensitive to the chilling temperature.

b. Relative humidity for the fruits and vegetables during their storage is important because it influences water losses and cause damage the quality. For example, wilted green may require excessive trimming. Most fruit and vegetable crops can retain better quality at relative humidity which can be 80 to 95 percent.

Table 5.2 Bad effect of Ethylene during storage

Ethylene effect during storage	**Crops**
	Reddish brown spotting of lettuce in the midrib of leaf
	Loss of green shading in snap bean
	Increment sturdiness in turnips and asparagus leaves
	Sharpness in carrot
	Yellowing and abscission of leaves in broccoli, cabbage, cauliflower
	Mellowing of cucumber and summer squash
	Mellowing and advancement of off flavour in watermelon
	Searing and staining in eggplant mash and seed
	Staining and off-flavour in yam
	Potato growing
	Increment aging and mellowing of develop green tomato

c. Sanitation facility in the storage can be a great concern in handling the produce because it isn't just securing the item against post-gather ailment, but shields shoppers from food borne disease too.
d. Ethylene is a characteristic hormone which promotes additional ripening of the produce when it is exposed to it. It can cause loss of quality, reduce shelf life and show symptoms of injuries.

ii. Transportation of the horticultural crops is done through rail or trucks in India. Therefore, the control of temperature and humidity, and adequate ventilation are required. Transportation with the help of refrigerated trucks is effective in preserving the quality of the product. Pre-cooled products can be transported with the help of well-insulated non-refrigerated trucks for many hours without any changes in the temperature which can be considered cost-saving as well as the quality of product is not sacrificed.
iii. There is a deterioration of the product quality because of the activity of bacteria and fungi which is already present on the surface of fruits and vegetables. These microorganisms physically and mechanically injure the quality of the fruits. So there are many entomological factors which can cause damage.
iv. Packaging is one of the important elements which protects fruits and vegetables from injury and water loss as well as it helps in convenient handling and marketing. There are two sorts of bundling: the first can be the point at which the produce is stuffed in compartments for transportation and while the other is when the produce is pressed into retail units. The ideal compartments for pressing products need to be simple.

Prevention of Losses

There are several factors causing damage to fruits and vegetables like physiological respiration, ethylene production, metabolic changes after harvest, physiological breakdown, chilling injury as well as various pathological damages. There are various ways to stop all this.

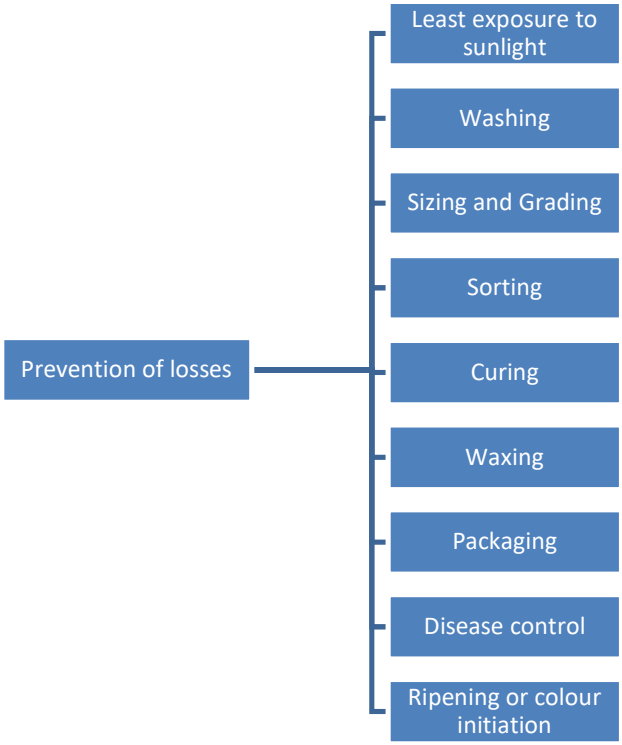


Fig. 5.10 Prevention of Loss

i. Regarding exposure to sunlight, fruits and vegetables should not be exposed to the direct daylight or direct warmth. They need to be stored in the shade before transportation. Operations related to handling such as washing, sorting, grading and waxing be undertaken before packing.

ii. Washing is necessary to meet the demand of the consumers for clean products free from external dirt. The purpose of washing after harvesting is to improve appearance. Low concentration of chlorine can be used to in wash water to prevent the spread of diseases which leaves no chemical residues on fruits and vegetables.

iii. Sizing and grading are essential before selling the product into the market. They are done before packaging in houses established in the country. There are private packers as well as National Dairy development Board which have their own packaging houses in the SAFAL chain. Grading is one of the important steps which ensures a uniform quality to fruits and vegetables for domestic and international trade. Grading can be done manually or with the help of machines on the basis of

- soundless,
- firmness,
- cleanliness,
- size,
- shape and colour,
- maturity,
- freedom from disease,
- mechanical injury,
- insect damage, etc.

iv. Sorting is a manual operation to detect unwanted fruits from entering the market. The fruit for sorting can be moved out of belt or roller conveyor. The purpose of sorting is to remove fruits that is not suitable for the sale. Sorting can be done on the basis of maturity, shape, colour and other physical parameters of fruits.

v. Curing is another method in case of vegetables particularly garlic, onion, potato and sweet potato. It is required during and after harvesting but before storage and marketing. Curing helps in healing harvesting injuries to reduce water losses and prevents the entry of taking decay causing organisms during storage. Curing is basically done in the field.

vi. In waxing the surface is covered with the food grade wax to reduce the loss of water to epidermal opening and replace the natural wax during the washing process. Basically wax is applied only to fruit type of vegetables such as tomato, capsicum, etc., and fruits like mango, banana, citrus, lime, etc. Waxing can be done after grading and fungicides may be added to wax.

vii. For packaging, the containers can be made of earthen pots, bamboos, basket sacks, boxes, logs, etc. Portions of the items are sent unloaded to the market in heaps. While transportation proper ventilation and heat are important to reduce the air and gas exchange and minimise water losses. There can be holes in the cartoons which can be at least 5% of the total box area. Wrong packaging can create a number of problems such as compression injuries.

viii. Disease control is also one of the concerns during packing. Heat treatment is suggested in the case of mango, papaya, etc.

ix. Ripening or colouring of fruits can also happen because of the application of ethylene. Banana, mango, tomato, etc., can change the shade.

To Do Activity

- List down the vegetables and fruits which can be saved from losses while packaging and waxing.
- Discuss the common fruits and vegetables produced and their traditional methods of harvesting.

5.3 Integrated Farming System

It can tackle the farmers' distress and focuses on:

- Utilisation of the by-product as an input which ensures supplementary and complementary enterprises reduce the effective input cost.
- All the component enterprises provide a consistent and stable pay at a more elevated level.
- Control of the creepy crawly bug sickness.
- Reduction in the utilization of synthetic manures and other destructive agrochemicals and give contamination-free produce to the general public.

Case Study

This system includes cropping, poultry, fisheries, livestock, vegetables and goat rearing. It was undertaken at ARS, Siruguppa, Karnataka in the wet and dry season of 2003-04 and 2004-05. It was conducted to study the productivity, profitability, employment generation, energy flow and water requirement over traditional system in Tungabhadra project. It recorded 26.3% and 32.3% productivity and profitability over a period of time respectively compared with the conventional rice system. Out of all the components, the highest net returns were obtained from crops (63%), followed by goat rearing (30%), fisheries (4%) and poultry (1.3%). In terms of employment generation and water requirement, it has been found to be 275 manday/ha/year and 1247mm. respectively. Specific energy flow was 3.09 MJ/kg which was low in IFS. Channabasavanna et al., 2009.

Source: Channabasavanna, A. S., Biradar, D. P., Prabhudev, K. N. and MahabhaleswarHegde. 2009.

- Some of the element of coordinated cultivating frameworks like natural cultivating which build up a wise blend of pay age exercises like dairy, poultry, fisheries, goat raising, vermicomposting and others network drove the coming framework for water protection which can diminish the farmer's misery.
- It assists relieving the negative effect of farming and animals on conditioning case of north eastern farmers integrated farming. It can be an effective tool because it can be suitable particularly for the hilly region of North-eastern India.

Incorporated cultivating framework is one of the methodologies of cultivating practices which typically originated from China. It is used in raising coordinated fish cum pig cultivating, incorporated fish cum duck cultivating, incorporated fish cum fish cultivating chicken, coordinated fish cultivating cum cows cultivating, coordinated fish cultivating cum bunny cultivating and coordinated fish cultivating cum horticulture cultivating

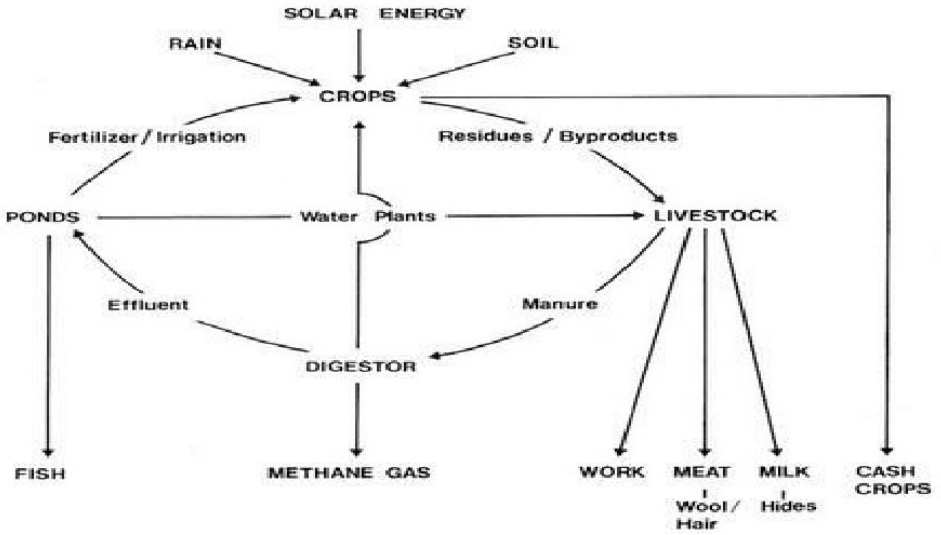


Fig. 5.11 Flow diagram for integrated farming systems (Preston and Leng, 1987)

Integrated practices farming makes the agricultural sector profitable which otherwise has been largely on a subsistence level. It can be understood by the fact that once there was degraded land in Rajasthan with poor crop production and income but with the use of integrated farming practices such as improved quality of crops, intercropping, honey bee keeping and a goat unit turned it into a major revenue generator along with improved quality of soil and decreased expenditure on fertilizers and pesticides which helped in the production of good quality fruits by using organic manure.

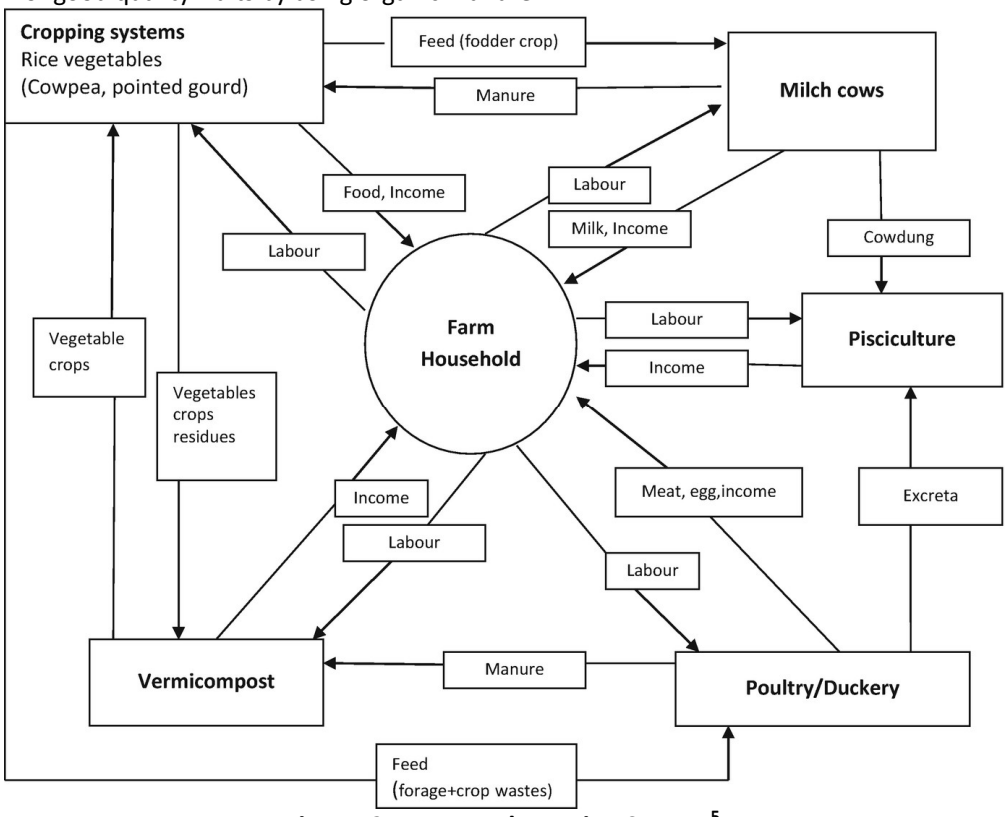


Fig. 5.12 Integrated Farming System[5]

[5] Source: Sohan S. Walia, Vikrant Dhawan, Ashok K. Dhawan and N. Ravisankar (2019)

Case Study

Regarding the financial viability of integrated farming system, various studies have been done in Thailand. A study conducted by Tokrishna in 1992 about the integration of duck raising, showed that the farmers gained a net benefit of US$1850 for every hac, of which 87% originated from fish with efficiency of 3.5t per hac. In the NakhonRatchashima and KhonKaen areas, Kaewsong et al. (2001) surveyed the financial status of 30% of the rancher individuals from the organization which advanced IFS in 2001. This mirrored the normal pay of individuals and was more than of the other territories in the Northeast district.

Source: Shamim M, Fouzia N and Momota Rani Debi (2011)

Integrated Farming System: Its Advantages for India

It can be the main response for the issues of expanding food production, higher income, and improvement in the nutrition of farmers with limited resource. By-products of the farming system can be inputs in complementary and supplementary enterprises.

- Reduction in the effective input cost.
- Revival of profitability and accomplishment of agro-natural harmony.
- Control of creepy crawly bug species and weeds.
- Crop cultivation alone cannot fulfil the demand of food and nutritional requirement and multicomponent farming is the only way out.
- It can increase profitability, enhance sustainability and preserve environmental quality.

To Do Activity

- Discuss the farming system in your locality and throw light on the advantages of the integrated farming system.

5.4 Agricultural Technology – Weather Aberrations, Weather Modification, Artificial Rain and Cloud Seeding

Climate abnormalities can do harm to the harvest and soil disintegration. Bad climate can influence the nature of item during transport just as the reasonability and life of seed can influence the planting material. In agriculture weather is an important determinant of the success of crops because most of them depend only on the weather conditions to provide sustainable water and energy. Apart from agriculture, allied activities such as livestock also depend upon the weather conditions. For production the livestock depends on the weather because adverse weather conditions sometimes cause loss of production, especially in the critical stage of growth. A combination of adverse weather elements which occur simultaneously can have a cumulative effect. Drought can be a situation when the water which is required can make an impact. What can be a condition when there is no precipitation in a stormy season.

A dry spell can be characterized into three classes based on the idea of effect and spatial degree.

- Meteorological dry season, when there is a precipitation, is somewhat shorter of certain level which is 75% of the climatological expected typical precipitation.
- Hydrological dry spell is where the hydrological assets like a stream waterway, lakes, etc. Where the surface water is exhausted and water level goes down the business power age and a lot more pay producing sources can be influenced, so the Meteorological dry spell is profoundly drawn than the hydrological dry season sets in.
- Agricultural dry spell is where the after effect of lacking precipitation is followed by the soil humidity content. Expert which brought about the soil humidity misses the mark to satisfy the need of the harvests in the development timeframe. Due to the dirt dampness accessible to a harvest in adequate it influences development lastly settled into the decrease of yield which is additionally named early season draught midseason draught and late season drought.

Flood

It is a situation when in the year genuine precipitation is over the ordinary by double the mean deviation or more is characterized as the time of flood or unreasonable precipitation. Like the draft the meaning of flood is additionally wearing as per the circumstance and starting with one locale then onto the next district. In a portion of the flood years is portrayed by the uncommon harm because of high and wearing escalated precipitation in India. In case of agriculture there are various examples of weather aberrations and their effect on agricultural sectors such as the draught, cyclones, flood, heat wave, seawater intrusion, etc. Agriculture, horticulture, livestock, poultry and fisheries are all getting affected.

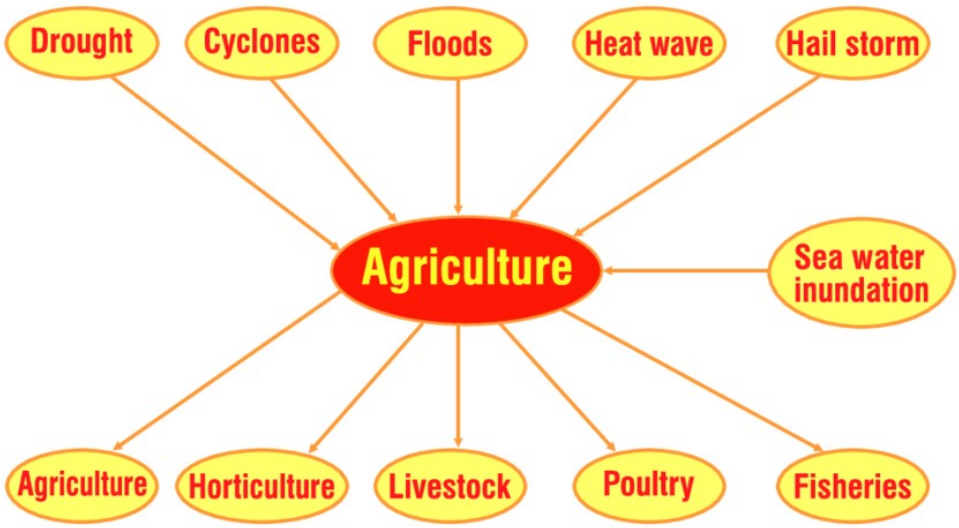


Fig. 5.13 Agriculture and Weather Aberrations (Srinivasa, 2015)

Role of Weather in Agriculture

Weather has a significant effect on agriculture. A crop needs a minimum of moisture. It is obvious that climate data can drive our business choices. It assists arranging productively limit the cost and expand the field just as benefit. Ranchers can take everyday premise identified with the climate conditions and there are essentially four essential territories of cultivating which are in a general sense influenced in the light of the climate sway. They are (a) crop development and application, (b) manure timing and conveyance, (c) irrigation and malady control, and (d) field functionality. They are the effect of weather condition which is changes and is decided by the farmers on the basis of weather.

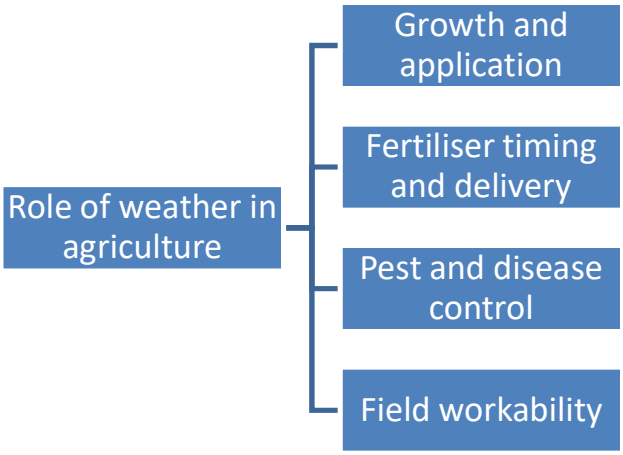


Fig. 5.14 Role of weather in Agriculture

- Crop growth requires an appropriate amount of moisture, light and temperature. Detailed and accurate historical real-time and forecasting of weather information is there to help for better understanding and track the growth status of the crop which helps the farmers to take decisions. If the data is available to the farmers, it can help them to take a cost-effective decision like whether and when the crop needs to be irrigated and how to be irrigated.
- Fertilizer timing and delivery are among the many decisions that farmers take. These decisions are very important. If the decision is not taken in a proper manner, it can wipe away the entire field profit. Weather forecasting is important to ensure that fertilizer is applied in the right conditions. In the dry weather conditions, it does help.
- Regarding the disease and pest control there are certain weather conditions which are a pre-requisite. Weather forecasting and guides incorporate the pest and disease modeling. Wind forecasting also plays a significant function in accepting choices as the harvest analyzers airplane that synthetic substances, fungicidal and insecticidal synthetic concoctions on plants from the over the ground which can be used when wind conditions are insufficient to make this sprayer compound miss its objective.
- Regarding the field usefulness, it implies the accessibility of days and are appropriate for field work that essentially relies upon the soil humidity and soil temperature as per the precise field-level climate data. It can assist farmers with surveying the functionality of their fields just as to turn out to be more productive for their everyday activities.
- The money saving advantage condition of the farmers just as their cultivating conditions relies upon the climate figure data. It isn't in every case simple to evaluate yet this is a choice which can make effectively the majority of the huge cultivators and makers to take their choices. About different months farmers can settle on little yet cautious choices about their harvests and it would have accumulated effect on the financial implications of the decision which is made by the farmers which can have a significant impact on economic conditions.

Irrigation planning it is one of the good examples when farmers rely on the forecast for precipitation that turn out to be inaccurate and it can save the cost of unnecessary innovation expenses.

Importance of Weather Forecasting in Agriculture

The data about weather is significant in granting the field of horticulture where the cultivating practices can underscore precision and controlled use with regards to developing of harvest. This is one of the basic parts of the way to deal with the data innovation that can improve climate forecast and different things, for example, satellite and aeronautical nonexistent, GPS guide and sensors, drones, variable rate of manure applications and yield wellbeing markers. The principal motivation behind farming is to expand development proficiency and individual seed and plant mark. Agriculture depends on weather and climatic conditions and temperature matters when the farmer is deciding about growing different kinds of fruits, vegetables and pulses. When he doesn't have a proper understanding about the weather forecasting, he does his job on the basis of predictions. He may bear losses on the basis of fault detection of weather. But because of the development of technology and special weather forecasting mechanism, a farmer can get more accurate update about the weather on his smartphone.

Climate gauging is forecast which depends on the barometrical conditions in each area in specific timeframe where the territory can have various expectations identified with the state of climate which makes it extremely simple for the ranchers to know how, what to do and when. There are various indicators of whether such as temperature, sunlight, rains, etc., which have an effect on the crop forecasts. Weather can help for suitable planning and farming operations to irrigate the crop or not, when to apply fertilizers or whether to start complete harvesting or withhold it.

- Irrigation is one of the artificial applications of water to crops. The requirement of irrigation for the crop is affected by the variability of weather. So is the amount and timing of the evapotranspiration. These are two important indicators for the weather-related requirements. Time for the application of fertilizers is also significant and it has an impact on the crop yield. Besides reducing nutrient losses as well as preventing damage to the environment their application in the wrong time can damage the crop.

Weather Modification

Weather modification can be attempted by human activity both at the local as well as regional levels. It is also called weather control affected by way of cloud seeding.

Cloud Seeding

- Cloud seeding for the downpour or snow can be utilized to build water flexibly. Climate changes have some other results like hurricane, hail storms and storms.
- It may mean a sort of climate alteration which may change precipitation which tumbles from the mists by scattering substances into the air which fill the need of the cloud buildup or Ice cores that can adjust the miniature physical cycles inside the cloud.
- The reason for it is to build the downpour or moderate it. In India cloud seeding was attempted in 1983, 1987 and 1994 by Tamilnadu Government as there was a serious dry spell. In 2003 and 2004 Karnataka Government tried it.
- The strategy for cloud cultivating is that synthetic compounds are utilized for the mists covered up or silver iodide, potassium iodide and dry ice that is as strong carbon dioxide. Liquid propane is a gas can also be used. It can deliver ice gems in a higher temperature. It can be done temperature inside the cloud or between 4 and 19 degree Fahrenheit. There is a substance called silver iodide which is like ice that can incite freezing nucleation.

- A typical cultivating system can be founded on the way that it will bring fume weight lower than water. On account of mid height mists to use the Ice particles is supercooled mists permits those particles to develop to the detriment of fluid beads if there is adequate development can happen the particles can turn out to be extremely hefty so it can fall regarding precipitation from the mists else it can create no precipitation this cycle is called as static cultivating.
- Cloud seeding chemicals can be dispersed through the aircraft.
- It uses an increase in the preparation of precipitation about the clouds by adding the external agents. External and foreign particles are rushed in the cloud that can be dry ice, strong carbon dioxide, silver iodide, salt powder, etc.

Artificial Rain

- The cycle of downpour work starts from the dissipation of water from the sea or some other water body. When the dry season comes it implies that there are a few mists which do not downpour. Counterfeit precipitation is the idea which has stimulated where the temperature of the cloud is near zero and afterwards it tends to be gems of ice in the water fumes. Indeed, the downpour can come as a fake downpour. The cycle of counterfeit downpour resembles three stages: tumult, developing stage and cultivating.
- In Agitation this is the main stage which incorporates the utilization of synthetic substances. It invigorates the air masses upside of target region. Synthetic substances can ingest the water fume and it helps during the time spent on the buildup.
- The phase of building upstage is the second stage where the mass of the cloud is developed by urea dry ice pack or it can expand the thickness of the cloud.
- The third and last stage is called cultivating. This is seeking after the fake downpour. That is the reason why dry ice or iodide is besieged with the pressurized canister based on the cloud which assists building the dots of water and then ultimately rain comes.

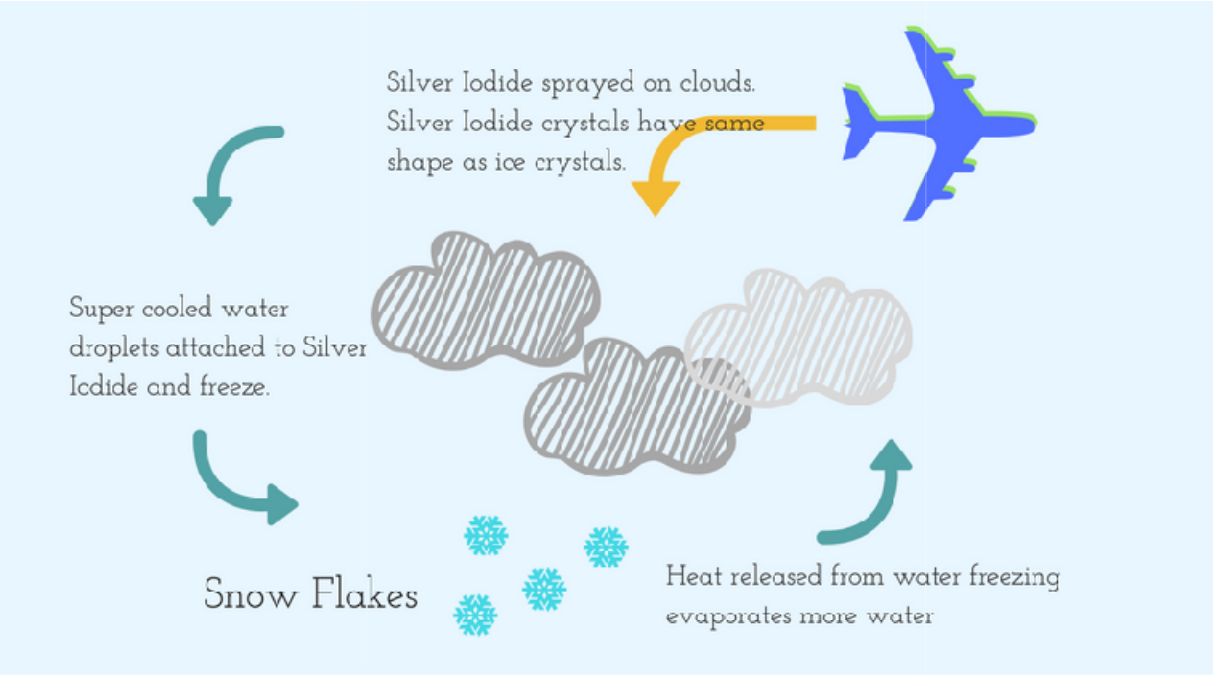


Fig. 5.15 Artificial rain formation

Remote Sensing

In remote sensing a farmer observes the field to evaluate its conditions without being there. If there is an occurrence, it is detected by far off pictures taken from the satellite and the airplane evaluates field conditions without physical touch with them. Far off Sensing can create the picture which is utilized to show water effectiveness, etc. Distant Sensing can be applied for observing vitality of the plants can be communicated through the leaf which the sensor can identify and reflect. What's more, the information can be sent to the ground station which can be shown on the field map.

Remote Sensing Application in Agriculture

Application of Remote sensing can be done in agriculture where the process involves the interaction between incidence reaction and the target of interest. This is a useful electromagnetic radiation in remote sensing that includes visible light near infrared and short-wave Infrared. A report given by the FAO estimates that to meet the world food requirement by 2050, food production needs to be increased by 60%. Various efforts are being done to increase the overall production to feed the population. Remote Sensing techniques can be applied to explore agricultural applications such as crop discrimination, acreage estimation, crop assessment, soil estimation, precision agriculture, soil survey, etc. The application of remote sensing in agriculture can be in case of crop and soil which is complicated because of dynamic and inherent complexity of eligible materials and soil. This technology provides advantages over the traditional method of agricultural survey:

- Capability of synaptic view.
- Capability of repetitive coverage to detect the change in low-cost involvement.
- Higher accuracy.

There can be various applications of remote sensing in agriculture such as crop anticipation, appraisal of crop harm and yield progress, crop recognizable proof, crop modelling and assessment, crop infection, etc.

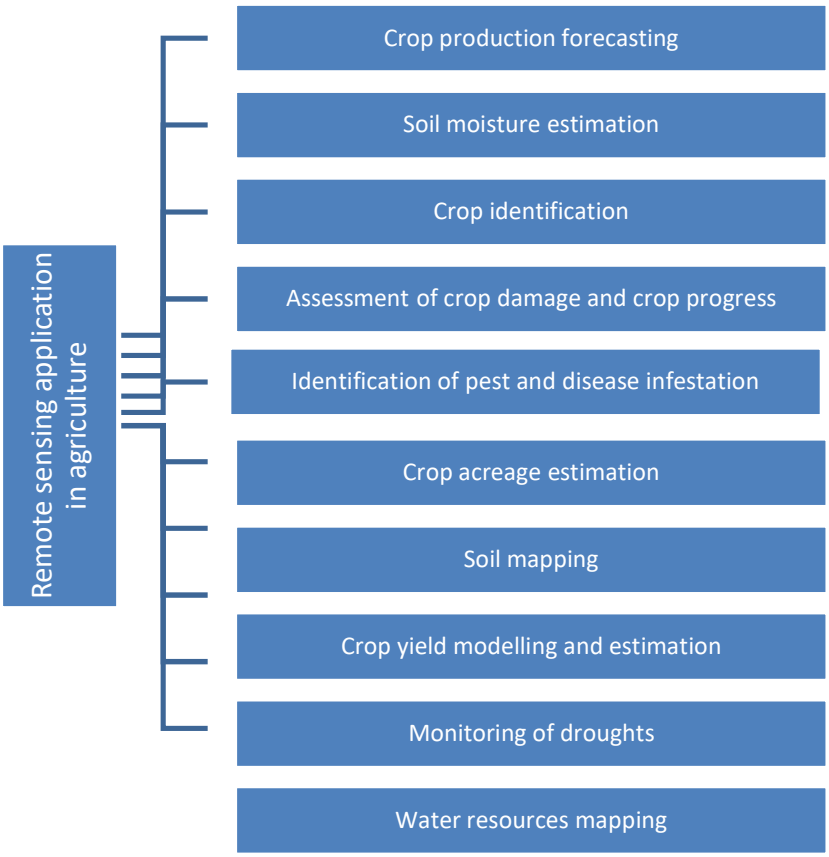


Fig. 5.16 Remote Sensing Application in Agriculture

- Remote sensing can be used to forecast the expected crop production as well as its productivity which determines how much crop can be harvested.
- Crop progress and damage can be assessed by remote sensing as it penetrates into the farmland.
- Crop identification shows the crop data which can be collected and taken to the laboratory.
- Crop acreage estimation can be done.
- Remote Sensing is useful harvest assessment and specialists can foresee the normal yield for a given farmland by assessing the yield.
- Soil humidity can be estimated as well as the nature of humidity the soil and find out which crop can be grown. This is called soil planning.
- Soil mapping can help the farmers in precision agriculture.
- Drought monitoring can also be done and when the rains will come can be learnt.
- Water resource mapping can also be done to know where the water resources are available and whether they are adequate.

To Do Activity

- Discuss the use of remote sensing in agriculture and its impact on agricultural productivity.
- Discuss the pro and cons of the artificial rain.

Remote Sensing Process

It includes various steps: (a) the sun discharges the electromagnetic vitality to the plants, (b) some of it is communicated through the leaves. (c) For this sensors of the satellite distinguish the reflected vitality. (d) The information is communicated to the ground station. (e) The information is examined. (f) It is showed on the field maps.

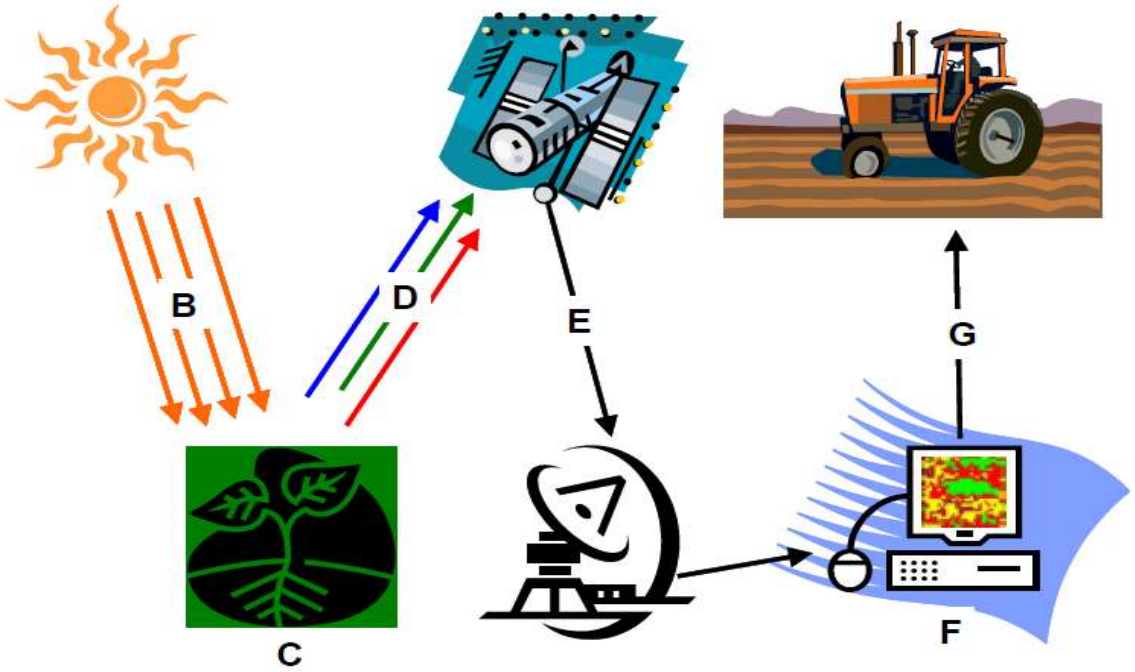


Fig. 5.17 The remote sensing processes

5.5 Modern Agricultural Farming - Hydroponics

Hydroponic system is a system where the crops can be grown without the use of soil. Plant roots are suspended either in a static liquid solution or can grow. It is soilless farming. Plant roots can be grown in a liquid solution inside the earth in materials like rock. New technologies are developing which can save water and hydroponics is one of them.

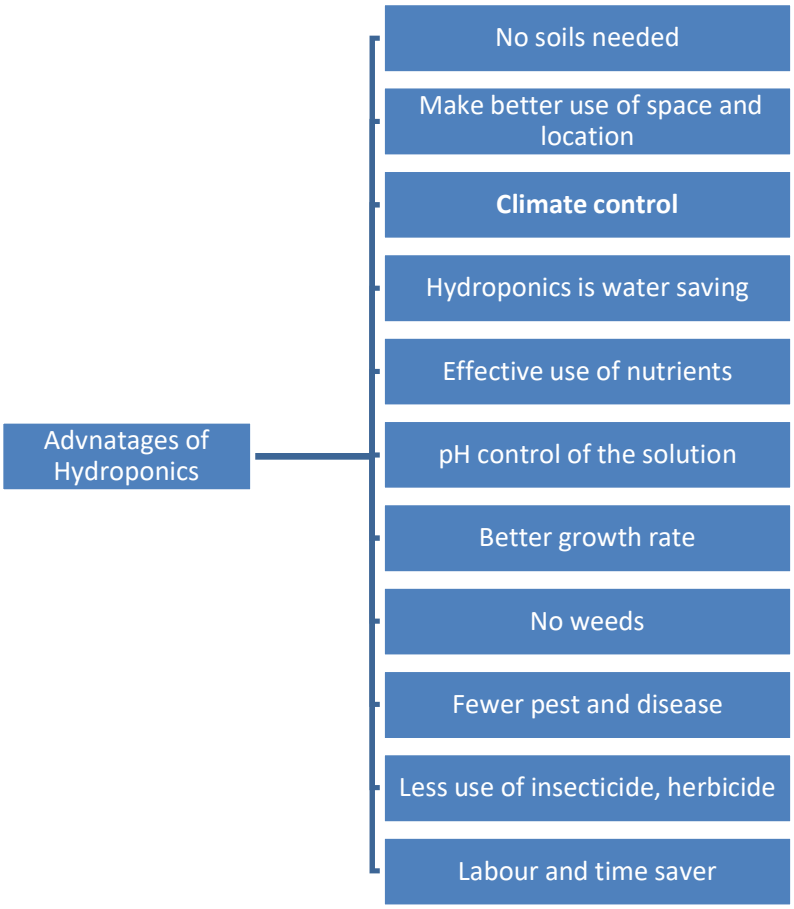


Fig. 5.18 Advantages of Hydroponics

- There is no water requirement and it can be considered as the farming of the future.
- It can make a better use of space and a lot of room is not required. In aqua-farming roots can be sunk into a tank is loaded with oxygenated arrangements in contact with the indispensable minerals.
- Like greenhouses, hydroponics is in totally control situations where temperature, humidity, light intensity, composition of the air, etc., are controlled so that can grow food around the year as well as is regardless of any season.
- It is a water sparing technique since it uses just 10% of water in contrast with the field grown crop. In this technique water is recycled and runoff can be captured and returned into the system. Water will become a critical issue in the future when food production is required to increase along with the water constraints.
- There is a proper utilisation of nutrients as there is an almost cent percent control of the nutrients, which plants need. Before planting, the producer can check the requirement of plants for nutrients, and the specific amount of nutrients according to that a particular stage can be put.
- All the minerals in the water are used.
- Various factors like temperature, light, moisture and nutrient can be controlled and under observation. It is an ideal condition for the plants to take them from the root system. Therefore, there is no longer wastage of valuable energy sources as well as they can dilute into the soil.

- weeds consume time to uproot or to treat, but here there is no weed or less weeds. That's why most of the time-consuming tasks such as gardening, tillage, ploughing, mowing, etc., are not required.
- Because it is soilless, soil borne pests and diseases do not exist. The plants can grow indoor in a closed system and the gardener can maintain them.
- The use of herbicides and pesticides is reduced making plants cleaner. It also cuts the cost of insecticides and herbicides.
- There is less work related to labour such as watering, cultivating, tillage, fumigation for weeds and pests etc.

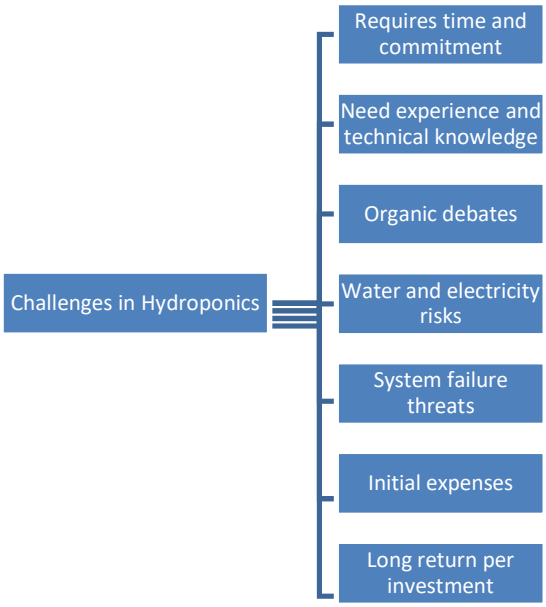


Fig. 5.19 Challenges in the Hydroponic system

There are disadvantages and challenges in hydroponics. It requires commitment, experience and technical knowledge. There are initial expenses.

To Do Activity

- Discuss the pros and cons of the modern agricultural technologies with especial focus of Hydroponics.
- List the other modern techniques for agriculture technologies in your locality.

References

- Channabasavanna, A. S., Biradar, D. P., Prabhudev, K. N. and MahabhaleswarHegde. 2009. Development of profitable integrated farming system model for small and medium farmers of Tungabhadra project area of Karnataka, Karnataka J. Agric. Sci., *22(1): 25-27*.
- Dumanski and Peiretti (2013). *Modern concepts of soil conservation*, International Soil and water conservation research, Vol 1, No 1, 2013, pp 19-23
- FAO, (2001). *Defining conservation agriculture. In: the economics of conservation agriculture*, FAO, Rome, Italy. www.fao.org/do.crep/004/Y2781E/y2781e)3.htm

- John Nowatzki, Robert Andres and Karry Kyllo (2019), Agricultural Remote Sensing Basics, Geospatial technology, National Institute of Food and Agriculture, USDA, Retrieved from https://mapasyst.extension.org/ agricultural-remote-sensing-basics/
- Mamun, Nasrat, Momota Rani Debi (2012), Integrated Farming system: Prospects in Bangladesh, *Journal of Environment Sciences and Natural Resources*,
- Misra RD., and M. Ahmed, (1987). *Manual on Irrigation Agronomy*, Oxford and IBH publication, New Delhi
- Preston, T. R. and Leng R. A. 1987. *Matching Ruminant Production Systems with Available Resources in the Tropics and Sub-Tropics*. Chapter 2.
- Reddy S.R., (1999). *Principles of Agronomy*. Kalyani Publishers, New Delhi.
- Sohan S. Walia, Vikrant Dhawan, Ashok K. Dhawan and N. Ravisankar (2019), Integrated Farming System: Enhancing Income Source for Marginal and Small Farmers, Natural Resource Management: Ecological Perspectives, Springer Link, pp 63-94
- Shamim Al Mamun , Fouzia Nusrat and Momota Rani Debi (2011), Integrated Farming System: Prospects in Bangladesh, Journal of Environ. Sci. & Natural Resources, 4(2): 127-136, 2011 ISSN 1999-7361
- Srinivasa Rao, B. Venkateswarlu, A.K. Sikka, Y.G. Prasad, G.R. Chary, K.V. Rao, K.A. Gopinath, M. Osman, D.B.V. Ramana, M. Maheswari and V.U.M. Rao (2015).*District Agriculture Contingency Plans to Address Weather Aberrations and for Sustainable Food Security in India*. ICAR-Central Research Institute for Dryland Agriculture, Natural Resource Management Division, Hyderabad - 500 059, India. 22.
- Srinivasarao, Gopinath, Prasad, Ramana, RavindraCharya (2019),Agriculture contingency plans for managing weather aberrations and extreme climatic events: Development, implementation and impacts in India, *Advances in Agronomy*, Vol 159, 2020, https://doi.org/10.1016/bs.agron.2019.08.002
- Tokrishna, R. 1992. Integrated livestock-fish farming systems I Thailand. In: Mukherjee, T.K., Moi, P.S., Panadam, J.M., and Yang, Y.S. (Eds.). *Proceedings of the FAO/IPT Workshop on Integrated Livestock-Fish Production Systems*, 16- 20 December, 1991. Institute of Advanced Studies, University of Malaya, Kuala Lumpur, Malaysia.
- Valdemar Hercilio de Freitas (2000). *Soil management and conservation for small farms, Strategies and methods of introduction, technologies and equipment,* A joint publication Land and Plant Nutrition Management Service FAO Land and Water Development Division and Agricultural Engineering Branch FAO Agricultural Support Systems Division, Experiences from the State of Santa Catarina, Brazil, FAO SOILS BULLETIN 77, ISSN 0253-2050

Model Questions

1. Differentiate between organic farming and sustainable farming.
2. What are the benefits of sustainable agriculture over the conventional agriculture?
3. What are the post-harvest management practices? Explain in the context of packaging and curing.
4. What are the bad effects of ethylene production on fruits and vegetables and how it is related to spoilage of produce?
5. Discuss the mechanism to prevent losses of fruits and vegetables.

6. Explain the integrated farming system with examples.
7. Discuss weather aberrations with special emphasis on droughts and floods.
8. What is the requirement of weather modification?
9. Discuss the relevance of artificial rains and cloud seeding.
10. What is the importance of remote sensing in agricultural development?
11. What are the advantages and disadvantages of hydroponics?

Editors' Profile

Dr W G Prasanna Kumar

Dr. W G Prasanna Kumar, Chairman, Mahatma Gandhi National Council of Rural Education (MGNCRE) prides in calling himself a Public Servant working for Climate Change. His expertise in Disaster Management has him in the advisory panels of several state and national level departments. He is also an expert advisor for the government of Telangana in its Disaster Response Force endeavour. A master trainer for Civil Services candidates, he conducts intensive training programs periodically at the behest of nationally recognized training institutes. He is currently actively involved in promoting higher education curriculum addressing rural concerns in India. **"Villagers to be producers not just consumers"** is his conviction that drives him to work for rural challenges. He aspires for an adaptive disaster risk resilient and eco-responsible India. The Curriculum on MBA in Waste Management and Social Entrepreneurship, and BBA and MBA in Rural Management are his major academic achievements dedicated to India's rural concerns. This has culminated in several collaboration MOUs for introduction of MBA/BBA Rural Management in Higher Education Institutions across India.

Dr. Prasanna Kumar excels in taking a vision and making it a reality and a plan into action, driven by a strong motive to achieve. He has translated positive intentions into tangible results. Being clear on the vision, defining a pathway, setting of the track with a clear destination point and quickly taking corrective actions as and when needed – are his prime qualities that make him an Achiever.

Under Dr. W G Prasanna Kumar's leadership MGNCRE has done nationally recognized instrumental work in building rural resilience including rural community engagement and Nai Talim - Experiential Learning. He has guided and helped MGNCRE in making key decisions and implementing agenda in several areas including Nai Talim (Experiential Learning), Community Engagement, Rural Immersion Programmes, Swachhta Action Plan activities, Industry-Academia Meets and Exhibitions on Waste Management, Comprehensive Sanitation Management in villages by working with Higher Educational Institutions, making curricular interventions in Waste Management and Rural Management, compiling Text Books on Waste Management and Rural Management, UNICEF (WASH) activities and several other related impactful activities. MGNCRE has become an interface for Government of India for promoting academic activity focusing on the rural concerns, being an advisor and a curriculum development agency for the Government of India. The Council is also now an RCI for Unnat Bharat Abhiyan.

Another pathbreaking achievement has been the formation of **Cells** through online workshops for institutionalising the efforts of MGNCRE. Vocational Education-Nai Talim-Experiential Learning (VENTEL) discuss MGNCRE's interventions in HEIs and making Vocational Education as a Teaching Methodology; Workshops on Social Entrepreneurship, Swachhta and Rural Engagement related activities in Higher Education Institutions has paid dividends and the key roles of the HEIs is highly appreciated by the Ministry. Building continuity and sustainability is being done through Social Entrepreneurship, Swachhta & Rural Engagement Cells (SES REC). Institutional level Rural Entrepreneurship Development Cells (REDC) Workshops/ FPO/FPC-Business Schools Connect Cells (FBSC) are organized with the objectives of Functionality of RED Cell; Preparation and Implementation of Business Plan and grooming students to be Rural Entrepreneurs.

A man with many firsts to his credit, and an incredible record of accomplishments, Dr. W G Prasanna Kumar is currently guiding MGNCRE in building a resilient rural India.

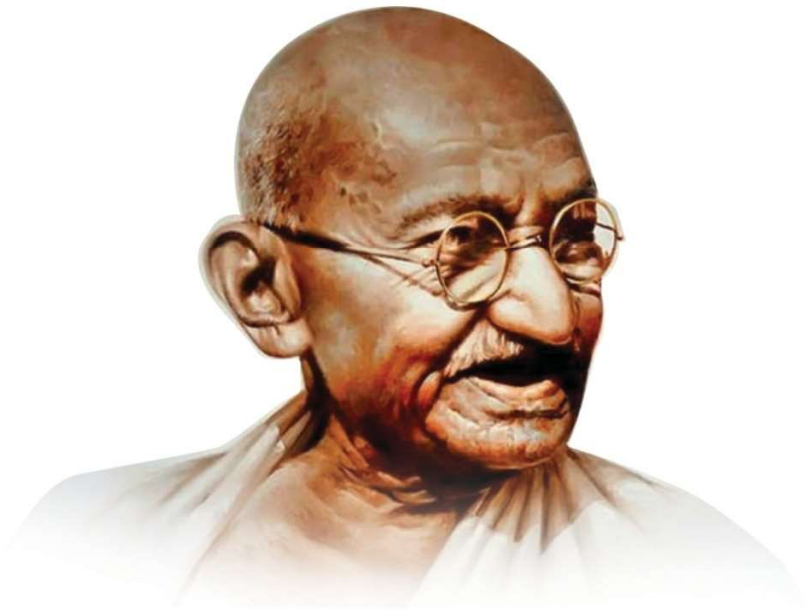
Dr K N Rekha

Dr K N Rekha, is a PhD Graduate from IIT Madras. She has 14 years of experience in training and education Industry. She works at Mahatma Gandhi National Council of Rural Education (MGNCRE), Hyderabad as Senior Faculty. She is involved in curriculum development on Rural Management and Waste Management. Prior to this, she worked as a researcher at Indian School of Business, Hyderabad, a short stint at Centre for Organisation Development (COD), Hyderabad. She has co-authored a book on "Introduction to Mentoring", written book chapters, peer reviewed research papers, book reviews, Case studies, and caselets in the area of HR/OB. She also presented papers in various national and international conferences. Her research areas include Mentoring, Leadership, Change Management, and Coaching. She was also invited as a guest speaker at prominent institutions like IIT Hyderabad.

Author's Profile

Dr Neelam Yadava

Dr. Neelam Yadava is on the faculty at Tata Institute of Social Sciences, Tuljapur Campus, since 2010. She has blended her wide experience in teaching, research and extension, focusing her attention on various issues. She is engaged in multidisciplinary researches including capacity building, rural economy, entrepreneurial management, rural development, agricultural extension services, information technology, development communication and National Agricultural Innovation Project in her academic career. She has worked with the Indian Council of Agricultural Research Project of NAIP in North West Himalaya. She has completed her study from G.B. Pant University of Agriculture and Technology with specialization in Agricultural Extension and Communications (Major) and Social Sciences (Minor). She has participated in national and international seminars/conferences as a paper presenter as well as an organizer. She has organized many workshops and confluences on entrepreneurship.



सत्यमेव जयते

Mahatma Gandhi National Council of Rural Education (MGNCRE)

Department of Higher Education

Ministry of Education, Government of India

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there is Universal Prosperity

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