AGRICULTURE

Definition: Agriculture is a Latin word. Agri means farming/raising crop and “cultura” means cultivation.

“Agriculture is a science, and an art as well as a business of raising crop and rearing of animals to meet the basic necessities of mankind through exploiting natural resources (soil, water, climate) to provide food, fiber and shelter.’’

History of Agriculture

Agriculture involving domestication of plants and animals was developed at least 10,000 years ago, although even earlier people began altering plant and animal communities for their own benefit through other means such as fire-stick farming. Agriculture has undergone significant developments since the time of the earliest cultivation. The Fertile Crescent of Western Asia, Egypt and India were sites of the earliest planned sowing and harvesting of plants that had previously been gathered in the wild. Independent development of agriculture occurred in northern and southern China, Africa's Sahel, New Guinea, parts of India and several regions of the Americas. Agricultural practices such as irrigation, crop rotation, fertilizers, and pesticides were developed long ago but have made great strides in the past two centuries. The Haber-Bosch method for synthesizing ammonium nitrate represented a major breakthrough and allowed crop yields to overcome previous constraints.

In the past century, agriculture in the developed nations, and to a lesser extent in the developing world, has been characterized by enhanced productivity, the replacement of human labor by synthetic fertilizers and pesticides, selective breeding, and mechanization. The recent history of agriculture has been closely tied with a range of political issues including water pollution, biofuels, genetically modified organisms, tariffs, and farm subsidies. In recent years, there has been a backlash against the external environmental effects of mechanized agriculture, and increasing support for the organic movement and sustainable agriculture.

Origins

Scholars have developed a number of hypotheses to explain the historical origins of agriculture. The transition from hunter-gatherer to agricultural societies, based on evidence from south west Asia and China, indicates an antecedent period of intensification and increasing sedentism known as the Natufian in south West Asia and the Early Chinese Neolithic in China. Current models indicate that a range of food resources was being used more intensively. Wild stands that had been harvested previously started to be planted. Evidence is also now emerging that the crops grown initially were wild and not domesticated. Crops such as emmer and einkorn wheat do not appear to have become domesticated until well into the Neolithic and 'ancient cultivated rice' (Oryza sativa) took 3000 years to become domesticated.

Localized climate change is the favored explanation for the origins of agriculture in the Levant. The fact that farming was 'invented' at least three times elsewhere, suggests that social reasons may have been instrumental. When major climate change took place after the last ice age (c. 11,000 BC), much of the earth became subject to long dry seasons.[citation needed] These conditions favored annual plants which die off in the long dry season, leaving a dormant seed or tuber. These plants tended to put more energy into producing seeds than into woody growth. An abundance of readily storable wild grains and pulses enabled hunter-gatherers in some areas to form the first settled villages at this time.

The Oasis hypothesis was proposed by Raphael Pumpelly in 1908, and popularized by Vere Gordon Childe who summarized the hypothesis in his book Man Makes Himself This hypothesis maintains that as the climate got drier, communities contracted to oases where they were forced into close association with animals which were then domesticated together with planting of seeds. The hypothesis has little contemporary support [citation needed], as the climate data for the time does not support the hypothesis.

The Hilly Flanks hypothesis, proposed by Robert Braidwood in 1948, suggests that agriculture began in the hilly flanks of the Taurus and Zagros Mountains, and that it developed from intensive focused grain gathering in the region.

The Feasting model by Brian Hayden suggests that agriculture was driven by ostentatious displays of power, such as throwing feasts to exert dominance. This required assembling large quantities of food which drove agricultural technology.

The Demographic theories were proposed by Carl Sauer and adapted by Lewis Binford and Kent Flannery. They describe an increasingly sedentary population, expanding up to the carrying capacity of the local environment, and requiring more food than can be gathered. Various social and economic factors help drive the need for food.

The evolutionary/intentionality hypothesis, advanced by scholars including David Rindos, is the idea that agriculture is a co-evolutionary adaptation of plants and humans. Starting with domestication by protection of wild plants, followed specialization of location and then domestication.

The Levantine Primacy Model was developed in the 1980s by Ofer Bar-Yosef and his collaborators. This provides a cultural ecology explanation, based on the idea that some areas were better favored with domesticable plants and animals than others.

The domestication hypothesis put forth by Daniel Quinn and others states that first humans stayed in particular areas, giving up their nomadic ways, then developed agriculture and animal domestication.

Another hypothesis is that humans were prevented from staying in one place for much of their history, due to the risk of attacks from other tribes.

The Innovation and Specialization Model was put forward recently by Rupert Gerritsen, in Australia and the Origins of Agriculture (2008). This hypothesis considers the question in terms of economic development and treats agriculture as a form of specialization arising from two factors, higher population densities and innovation in areas of higher net natural productivity, and long-term advantageous information acquisition at nodal points in communication in long range scale-free networks.

Importance of Agriculture

The agriculture sector is not only important at national level but also at international level. About fifty years back, the agriculture sector was neglected both in the developed and underdeveloped countries of the world. It was regarded as residual reservoir particularly of labor for employment in industries. In 1960's the importance of agriculture was realized and adequate attention was given to this sector. The importance of balanced growth of agriculture and industrial sectors was stressed by the development economists. In 1970's and since the beginning of 1980's, agriculture in the process of development, has gained increased significance.

Importance of Agriculture in Economic Development:

Pakistan is basically a farming community. About 70% of its population is living in rural areas and nearly 50% of them engaged in farming, livestock and agro-based industries. However, Agriculture sector plays a vital role in the economic development of a country. It is confirmed and supported by the following facts.

1. **Determination of GDP growth rate:** The GDP growth rate in Pakistan is mainly dependent upon the growth rate in agriculture sector. For example, the GDP growth rate increased from 4.5% in 1993-94 to 5.2% in 1995-96 mainly due to increase in the production of cotton, rice and wheat in the year 1995-96. It came down to 3.1% in 1996-7 due to fail in the production of cotton, wheat and sugarcane.
2. **Agricultural Development essential to curtail inflation:** If the rate of growth in agriculture sector is low, it brings shortage of food, vegetable, and other essential raw materials in the country. The prices of the essential goods go up. The slow rate or fall in the production of agriculture sector generates inflationary pressure and creates bottlenecks in the economic development of the country.
3. **Major component of GDP:** Agriculture sector is the single largest component of GDP in Pakistan. Its contribution is 25% to Pakistan's GDP. The progress of agriculture sector provides a sound base for economic development and is considered one of the preconditions for take off or self sustained growth.
4. **Providing labor force to industry**: In most of the developing countries (including Pakistan) agriculture is the main source of providing manpower of various sectors of

economy. In Pakistan, 50% of labor force is employed in agriculture sector. With the improved growth in the agriculture sector due to mechanization, the surplus labor force can be easily absorbed in the small and large scale industries. The provision of new employment both in the agriculture industrial and other sectors can increase the income of the workers and help them to get out of low income equilibrium.

5. **Foreign exchange earner:** The agriculture sector is the main source of foreign exchange earnings in Pakistan. The export of cotton, cotton based products, rice etc fetch about 65% of our total export earnings. This helps in the import of capital machinery, equipment, technical know how etc which essential inputs for development are. The availability for foreign exchange not only helps in the industrialization programme but also improves the balance of payments.
6. **Meets food requirements:** Pakistan's population is growing at an alarming rate of 2.77% annually. The agriculture sector is successfully meeting the food requirements of over 13 crore persons in Pakistan. Had there been no green revolution in agriculture sector during sixties and seventies, we would have spent the major portion of foreign exchange earned on the food import. The economic development would have also been retarded due to low capital formation.
7. **Support of industries:** The improved growth in the agriculture sector provides raw material to manufacturing industries. The production of cotton, jute, sugarcane, fruits etc enable the cotton, jute, sugarcane fruit processing and other agro based industries to get material from within the country and expand production. The industries not only meet the domestic requirements of cloth, sugar, jute bags etc but also earn foreign exchange by exporting them.
8. **Expanded industrial market:** The expanding and progressive sector brings prosperity to the agriculturists. The increase in the income of formers is spent on the purchase of industrial output such as clothes, motorcycles, cars, fans etc. The improvement in the agriculture sector thus provides on outlet for the products of the expanding industries.
9. **Marketable surplus:** When the agriculture sector is expanded on scientific lines, it yields handsome marketable surplus. The surplus which may be cotton, jute, wheat, sugar, silk, fish, timber etc can help to pay the import of industrial raw materials, capital equipments and technology. This helps in bringing about rapid economic development.

IMPORTANCE OF AGRICULTURE FOR PAKISTAN

Agriculture is very important for Pakistan. It helps the country in the development of economy. Every country has a vast land, which is used for agriculture. Pakistan is also an agricultural country. Its total area is 7, 96,096 square kilometers. 70% of our total population is living in the villages. The major source of their living is agriculture. Agriculture employed 66% of the total workforce in 1950-51 but by 1999-2000. This figure dropped to 47.3%. This shows that people are now not interested in farming. They are doing jobs in industry and other fields.

They are leaving farming and migrated to cities. Because cities have more chances of jobs. There are more factories and more development project offices. So, people move from villages and settle in the cities. Another reason in the villages is that, people are using tractor and machinery, so they need less people.

In Pakistan, the best area for agriculture is Punjab. Its soil is very fertile and its irrigation system is very fine. Its total is equal to quarter of the total area for Pakistan. But it has 57% of the total cultivated land. In Pakistan, we have two main crops, which are Kharif crops and Rabi crops. Kharif crops grow in Summer while Rabi crops grow in Winter.

The most important food crops in Pakistan are as following:

1. Wheat: - Wheat is a major need of our country. It is grown on a large area. This crop is sown in October and November and harvested in April and May.

2. Rice: - Pakistan produces over 4.3 million tons of rice.

3. Maize: - Maize is a Kharif crop that grows in warm places.

4. Millet: - These crops can grow even in poor soils.

5. Pulses: - Pulses are good source of protein.

The most important cash crop in Pakistan is following:-

1. Cotton: - Cotton is our leading exports. Pakistan produces 9.8 billions bales of cotton a year.

2. Tobacco: - Tobacco is also an important cash crop. The best tobacco growing areas are in Mardan and Peshawar.

3. Lives Stock: - Most of the milk comes from the buffaloes. Cow produces almost a million tons of milk a year.

Branches of Agriculture

Following types of agriculture which are as follow:

1. **Agronomy:** Branch of Agriculture which deals with the principle and practices of crop production & soil management.

2. Soil sciences
3. Horticulture
    a. olericulture
    b. floriculture
    c. land scaping
4. Entomology
5. Plant breeding and genetics
6. Plant pathology
7. Agri-economics
8. Food science and technology
9. Agriculture extension
10. Forestry
11. Fish culture

Salient Features of Pakistan Agriculture

Pakistan's principal natural resources are arable land and water. About 25% of Pakistan's accounts for about 21.2% of GDP and employs about 43% of the labor force. In Pakistan, the most agricultural province is Punjab where wheat and cotton are the most grown. Some people also have mango orchards but due to some problems like weather, they're not found in a big range.

1. **Crops:** The most important crops are wheat, sugarcane, cotton, and rice, which together account for more than 75% of the value of total crop output.
   Pakistan's largest food crop is wheat. In 2005, Pakistan produced 21,591,400 metric tons of wheat, more than all of Africa (20,304,585 metric tons) and nearly as much as all of South America (24,557,784 metric tons), according to the FAO. The country is expected to harvest 25 to 23 million tons of wheat in 2012. Pakistan has also cut the use of dangerous pesticides dramatically. Pakistan is a net food exporter, except in occasional years when its harvest is adversely affected by droughts. Pakistan exports rice, cotton, fish, fruits (especially Oranges and Mangoes), and vegetables and imports vegetable oil, wheat, pulses and consumer foods. The country is Asia's largest camel market, second-largest apricot and ghee market and third-largest cotton, onion and milk market. The economic importance of agriculture has declined since independence, when its share of GDP was around 53%. Following the poor harvest of 1993, the government introduced agriculture assistance policies, including increased support prices for many agricultural commodities and expanded availability of agricultural credit. From 1993 to 1997, real growth in the agricultural sector averaged 5.7% but has since declined to about 4%. Agricultural reforms, including increased wheat and oilseed production, play a central role in the government's economic reform package.

Outdated irrigation practices have lead to inefficient water usage in Pakistan. 25 per cent of the water withdrawn for use in the agricultural sector is lost through leakages and line losses in the canals. Only a limited amount of the remaining water is actually absorbed and used by the crops due to poor soil texture and unleveled fields.

Much of the Pakistan's agriculture output is utilized by the country's growing processed-food industry. The value of processed retail food sales has grown 12 percent annually during the Nineties and was estimated at over $1 billion in 2000, although supermarkets accounted for just over 10% of the outlets.

The Federal Bureau of Statistics provisionally valued major crop yields at Rs.504,868 million in 2005 thus registering over 55% growth since 2000[9] while minor crop yields were valued at Rs.184,707 million in 2005 thus registering over 41% growth since 2000. The exports related to the agriculture sector in 2009–10 are Rs 288.18 billion including food grains, vegetables, fruits, tobacco, fisheries products, spices and livestock.

2. **Livestock:** According to the Economic Survey of Pakistan, the livestock sector contributes about half of the value added in the agriculture sector, amounting to nearly 11 per cent of Pakistan's GDP, which is more than the crop sector. The leading daily newspaper Jang reports that the national herd consists of 24.2 million cattle, 26.3 million buffaloes, 24.9 million sheep, 56.7 million goats and 0.8 million camels. In addition to these there is a vibrant poultry sector in the country with more than 530 million birds produced annually. These animals produce 29.472 million tons of milk (making Pakistan the 4th largest producer of milk in the world), 1.115 million tons of beef, 0.740 million tons of mutton, 0.416 million tons of poultry meat, 8.528 billion eggs, 40.2 thousand tons of wool, 21.5 thousand tons of hair and 51.2 million skins and hides.

   The Food and Agriculture Organization reported in June 2006 that in Pakistan, government initiatives are being undertaken to modernize milk collection and to improve milk and milk product storage capacity.

   The Federal Bureau of Statistics provisionally valued this sector at Rs.758,470 million in 2005 thus registering over 70% growth since 2000.
3. **Fishery:** Fishery and fishing industry plays an important role in the national economy of Pakistan. With a coastline of about 1046 km, Pakistan has enough fishery resources that remain to be fully developed. It is also a major source of export earnings.
4. **Forestry:** About only 4% of land in Pakistan is covered with forest. The forest of Pakistan are a main source of food, lumber, paper, fuel, wood, latex, medicine as well as used for purposes of wildlife conservation and ecotourism.

Chapter 2 - AGRONOMY

DEFINATION:

"Branch of agriculture which deals with the principles and practices of crop production and soil management"

OR

"Agronomy is an art, science of raising field crops managing soil resources to meet the fundamental necessities of life."

OR

"Agronomy is a science and technology of producing and utilizing plants for food, fiber fuel by soil conservation."

TYPES OF CROPS:

* Arable/Agronomic crops
* Horticulture crops
* Forests

Arable/Agronomic crops:

These crops included wheat, maize, cotton, rice etc.

Horticulture crops:

These crops included fruits and vegetables.

Forests:

These crops included trees and plants.

WEEDS:

"Any plant out of its proper place is known as weed."

OR

"Any unwanted plant is known as weed".

PRINCIPELS OF CROP PRODUCTION:

The principles of crop production is as follow:

(for wheat)

*Improve cultural practices
*Good seed of approved and new varieties.
*Correct manuring at right time.
*Irrigation application at right/proper time.
*Adequate plant protection measures.

Ist timing of irrigation:

After 15 to 20 days.

2nd timing of irrigation:

After 20 to 25 days.

STAGES OF PLANT:

There are two types of plant stages.

*Vegetative growth
*Reproductive growth

Vegetative growth:

In this growth plant complete hight, size out elongate it stem number of leaves in vegetative growth.

Reproductive growth:

In this type of growth grain, fruit produce in reproductive growth.

TYPES OF PLANTS:

There are two types of plants.

*Determinate plants
*Indeterminate plants

Determinate plants:

The type of plant in which first the vegetative growth is completed then reproductive growth is started is called determinate plants.

E.g. Wheat

Indeterminate plants:

The type of plants in which the plants carry vegetative reproductive growth of the same time is called the indeterminate plants.

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Climate

Definition:

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years.

The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system The difference between climate and weather is usefully summarized by the popular phrase "Climate is what you expect, weather is what you get.

Over historical time spans there are a number of nearly constant variables that determine climate, including latitude, altitude, proportion of land to water, and proximity to oceans and mountains. These change only over periods of millions of years due to processes such as plate tectonics.
Other climate determinants are more dynamic: the thermohaline circulation of the ocean leads to a 5 °C (9 °F) warming of the northern Atlantic Ocean compared to other ocean basins Other ocean currents redistribute heat between land and water on a more regional scale. The density and type of vegetation coverage affects solar heat absorption water retention, and rainfall on a regional level. Alterations in the quantity of atmospheric greenhouse gases determines the amount of solar energy retained by the planet, leading to global warming or global cooling. The variables which determine climate are numerous and the interactions complex, but there is general agreement that the broad outlines are understood, at least insofar as the determinants of historical climate change are concerned

Climate of Pakistan

Climate is an average or general conditions of temperature, humidity, atmospheric pressure, rainfall of a place. The climate of Pakistan, on the whole is dry and extreme. It means that the summers are extremely hot and winters are extremely cold and there is a little rainfall during the year.
Pakistan lies in the moderate zone. The climate is usually arid, characterized by hallucinating summers and cool or cold chills, and broad variations among-sty extremes of temperature at arranged locations. There is little rain. These generality's should not, though, obscure the separate differences offered among particular sites.
For example, the coastal area lengthwise the Arabian Inundation is typically warm, while the arctic snow-covered edges of the Karakoram Variety and of other bushels of the far north are so cold date round that they are just accessible by world class climbers for a few weeks in May and June of apiece year.

Pakistan has are four seasons:
1- A cool, dehydrated winter from December from February.
2- A Hallucinating, dry coil from Demo through May.
3- The summer raining season, or southwest downpour period, from June from September.
4-The losing ground monsoon epoch of October and November.
The start and length of these periods vary rather according to location.

The climate in the assets city of Islamabad varies from standard daily low of 2° C in January to standard daily high of 40° C in June. Semi of the yearly rainfall happens in July and Imposing, averaging about 255 millimeters in apiece of those two months. The balance of the date has notably less rainwater, amounting to about fifty millimeters per month. Hailstorms are ordinary in the spring.

Pakistan's main city, Karachi, which is as well the bucolic's industrial middle, is further humid than Islamabad however gets less rain. Just July and Imposing average further than twenty five millimeters of rainwater in the Karachi area; the residual months are fantastically dry. The temperature is as well more identical in Karachi than in Islamabad, ranging from an standard daily low of 13° C during chill evenings to an standard daily high of 34° C on summer days. Though the summer temperatures do not find as high as those in Punjab, the high dampness causes the nation immense deal of discomfort.

Most areas in Punjab experience quite cool chills, often accompanied by rainwater. Woolen wraps are damaged by women and men for heat because few domiciles are angry. By mid February the temperature starts to rise; springtime weather persists until mid April, when the summer warmth sets in. The start of the southwest downpour is due to attain Punjab by May, however since the ancient 1970's the weather prototype has been uneven. The coil monsoon has also skipped over the area or has caused it to rainwater so hard that avalanches have effected. June and July are unjustly hot. Though official guess rarely arrange the temperature mentioned 46° C, bulletin sources maintain that it attains 51° C and often carry news about people who have yielded to the warmth. Heat records were busted in Multan in June 1993, whenever the mercury was accounted to have risen to 54° C. In Imposing the cruel heat is punctuated by the raining season, referred to as "BARSAAT", which realizes relief in its awakening. The hardest allotment of the summer is afterward over; however cooler weather does not come waiting late October.

Land of Pakistan

Pakistan is a land of many splendors. The Scenery changes northward from coastal beaches, lagoons and mangrove swamps to sandy deserts, desolate plateaus, fertile plains, dissected uplands and high mountains with beautiful valleys, snow-covered peaks and eternal glaciers.
This variety of landscape divided Pakistan into six major regions-
The Northern High Mountainous Region, the Western Low Mountainous Region, the Postwar Uplands, the Baluchistan Plateau, the Punjab Plain and the Sindh Plain.

The Himalayas

Stretching in the north from east to west are a series of high mountain ranges which separate Pakistan from China, Russia and Afghanistan. They include the Himalayas, the Karakoram and the Hindukush mountains. The Himalayas spread in the north-east and the Karakoram rises on the north-west of the Himalayas and extends eastward up to Gilgit. The Hindukush mountains lie in the north west of the Karakoram but extend eastward into Afghanistan. With the assemblage of 33 giant peaks over 7,315m, the region is the climbers' paradise. Many summits are even higher than 26,000 ft. (7,925m) and the highest K-2 (Mt. Goawin Ausün) at 28,250ft. (8,610m) is exceeded only by Mt. Everest. Inhospitable and technically more difficult to climb than even Mt. Everest, they have taken the biggest toll of human lives in the annals of mountaineering. The

very passes are rarely lower than the summit of Mt. Blonc and several are over 18,000 ft. (5,485m). The Karakoram Highway that passes through the mountains is the highest trade route in the world.
Besides, the region abounds in the vast glaciers, large lakes and green valleys which have combined at places to produce holiday resorts such as Gilgit, Hunza and Yasin in the west and the valleys of , Dir, Chitral, Kaghan and Swat drained by the rivers Chitral, Panjkora, Kunhar and Swat respectively in the east. Dotted profusely with scenic spots having numerous streams and rivulets, thick forests of pine and junipers and vast variety of fauna and flora, the Chitral, Kaghan and Swat valleys have particularly earned the reputation of being the most enchanting tourist resorts of Pakistan.
South of the high mountains, the ranges lose their heights gradually and settle down finally in the Margalla hills (2,000-3,000 ft.) in the vicinity of Islamabad, the capital of Pakistan, and swat and Chitral hills north of river Kabul.

The Western Low Mountains Region

These mountains spread from the Swat and Chitral hills in a north-south direction, and cover a large portion of N.W.F.P. North of the river Kabul their altitude ranges from 5,000 ft. to 6,000 ft. in Mohmand and Malakand hills. The aspect of these hills is exceedingly dreary and the eye is everywhere met by the dry rivers between long rows of rocky hills and crags, scantly clothes with coarse grass, scrub wood and dwarf palm.

South of the river Kabul spreads the Koh-e-Sofed Range with a general height of 10,000 ft., its highest peak Sakaram being 15,620 ft. South of the Koh-e-Sofed are the Kohat and the Waziristan hills (5,000 ft.) which are traversed by the Kurram and Tochi rivers, and are bounded on south by Gomal river. The whole area is a tangle of arid hills composed of limestone and sandstone.

South of the Gomal River, the Sulaiman Mountains run for a distance of about 300 miles in a north-south direction, Takhte Sulaiman (11,295 ft.) being its highest peak. At the southern end lie the low Marri and Bugti hills.

South of the Suliaman Mountains is the Kirthar Range which forms a boundary between Sind plains with Quetta in Baluchistan Plateau. It consists of a series of ascending ridges running generally north and south with broad flat valleys in between. The highest peak named Kute ji Kabar (dog's grave) is 6,878 ft. above sea-level.

The Western Mountains have a number of passes which are of special geographical and historical interest. For centuries they have been watching numerous kings, generals and preachers passing through them, and the events that followed brought about momentous changes in the annals of mankind. Khyber Pass, the largest and the most renowned of these is 35 miles long and connects Kabul in Afghanistan with the fertile vale of Peshawar in N.W.F.P. the Tochi Pass connects Ghazni in Afghanistan with Bannu in Pakistan and the Gomal Pass provides a route from Afghanistan to Dera Ismail Khan which overlooks at the Punjab plains. The Bolan Pass connects the Sind plains with Quetta in Baluchistan and onward through Chaman with Afghanistan.

Enclosed by the branches of western mountains are a number of fertile plains which have been formed by rivers rising from these mountains and falling into Indus.

The Balochistan Plateau

The Balochistan Plateau extends westward, averaging more than 1,000 feet in elevation, with many ridges running across it from northeast to southwest. It is separated from the Indus Plain by the Sulaiman and Kirthar ranges. It has a remarkable indigenous method of irrigation called the karez, which consists of underground channels and galleries that collect subsoil water at the foot of hills and carry it to the fields and villages. The water is drawn from the channels through shafts that are sunk into the fields at suitable intervals. Because the channels are underground, the loss of water by evaporation is minimized. The technology for the construction of the karez probably came from western China, brought into Balochistan by the Buddhist monks who traveled back and forth over the Karakoram Range. The plateau is an extremely arid country and is the most sparsely populated region in Pakistan. Pastoral activity supplements a primitive form of agriculture. True pastoral nomadism survives in the northwest. Goats and fat-tailed sheep account for the majority of the stock, and much of the local traffic consists of camels and donkeys, although trucks and buses are in use on the new roads.

The Desert Areas

The desert areas include the steppes of the Sindh Sagar Doab (at its centre is the Thal, which has true desert conditions) and Cholistan in the Bahawalpur region (Punjab), which is known as the Nara or Registan in the Khairpur region (Sindh) and as the Thar Desert in the Thar Parkar region of southeastern Sindh. All these areas are extensions of the Thar Desert of western India.

Water resources of Pakistan

Indus valley, cradle of ancient civilization: The Indus valley has been the cradle of ancient civilization like those of the delta area of the Nile and the valleys of the Tigris and Euphrates. These three areas were the contemporary regions in which great civilizations flourished, about four to five thousand years ago. However, recent archaeological findings reveal that the Indus valley civilizations probably antedated that of the Tigris and the Euphrates. Excavations in the Indus valley have revealed that the dwellers of Moenjo-Daro, Kot Diji, and Harapa had established powerful empires. A stroll through the ruins of Moenjo-Daro and Harapa reveals that the houses in these cities were provided with all types of amenities. There were comfortable bedrooms, guestrooms, dinning rooms, porter's lodges, lavatories, handsome courtyards, drainage, fresh water wells, and tanks. The dwellings of Moenjo-Daro period are found so well finished and highly polished that these even match with that of today's then of prehistoric.

It is believed that the ancient people of the valley of Indus were outstanding in the field of agriculture and industry as compared to the civilization of contemporary period in Egypt and Mesopotamia. The textile crafts made from cotton are living examples of their expertise. Such was the glory of the ancient people of Indus valley; perhaps they were the first sedentary farmers of the world. The richness and wealth of the Indus valley was the greed of the foreigners. The valley of Indus has always been the cherished goal of the invaders and conquerors that followed one after another from the northwestern passes through the mountain ranges. The Aryans, the Iranians, the Graeco-Bactrians, the Parthenians, the Kushans, the white Huns, Muslims emperors, and Britishers plundered the rich valley of the Indus from time to time and ruled over the valley and northern India. Entire history of Indus valley reveals that one invader or another has treaded the present Pakistan. The Muslims of the sub-continent first tried to shake off a century old rule of British in 1857 and finally succeeded to drive them away in 1947, and the great valley Indus became part of Pakistan. Pakistan lies between latitudes 24 degree and 37 degree North and longitudes 61 degree to 76 degree East. Its surroundings include Iran on the west, Afghanistan on the northwest, Gilgit Agency, Azad Kashmir and disputed territory of Jammu and Kashmir lie on the northeast, India on the east and the Arabian Sea exists on its south.

Catchments of Indus river system: The Indus basin is a part of the catchments of the Indus river system that includes the northwest mountains, the Katchi plain, desert areas of Sindh, Bahawalpur, and the Rann of Kachh. The Indus and its major tributaries flow in longitudinal valleys in structural troughs paralleled to the mountain and invariably take an acute bend descending to the alluvial plains by cutting through mountains. These plains are stretched over a distance of 1528 Kilometers (950 miles) to the tidal delta near the Arabian Sea. The total catchment area of Indus River system spreads over 944,573 square kilometers (364,700 square miles). Of which 553,416 square kilometers (213,674 square miles) exist in Pakistan with a varying width of over 320 kilometers (nearly 200 miles) in the Punjab to about 80 kilometers (50 miles) in the narrow neck between the Thar Desert and the Khirthar mountains. The flat plain of Indus basin is made up of highly fertile alluvium deposited by the river Indus and its tributaries. Agriculture is concentrated essentially to this plain, where it has been developed by harnessing principal surface water resources available. Since, evaporation is high with meager and unreliable rainfall over Indus plains, hence, agriculture is wholly dependent on irrigation supplies. The river Indus and its tributaries are like a funnel, they rise in the northern mountain areas, receive water from various resources (snow, glacier melt, and rainfall), converge into a single stream at Panjnad (Mithankot), cover about 1005 Kilometers (625 miles) through the Sindh province, and finally discharge into Arabian sea.

Historical perspective: The Almighty Allah has gifted Pakistan with abundant water resources with water flowing down the Himalayas and Karrakurram heights from the world's largest glaciers, a free and unique bounty of nature for this land of alluvial plains. As a result of this natural resource, today we have the world's marvellous and the largest contiguous irrigation system that currently irrigates over 16 million hectares of land, out of 34 million hectares of cultivable lands available. This land lies within the plains formed by river Indus and its tributaries. Britishers started the barrage irrigation system during 1930s. However, before that the residents of Punjab, Sindh, and Frontier had constructed a number of inundation canals to irrigate their lands. In the Punjab, 38 such canals had been taken out of Sutlej, Indus, and Chenab rivers to irrigate areas around Bari Doab, Multan, Muzaffargarh, and Dera Ghazi Khan. In Sindh, water level of the Indus during summer had always been higher than the surrounding lands, thus, 16 inundation canals in this area had conveniently carried out the irrigation water during past century. However, British Army Engineers undertook construction and improvement of several irrigation canals in the sub-continent. Subsequently, construction works on Bari Doab Canal; Sidhnai Canal, Lower Sohag, Ramnagar Canal, Lower Jhelum Canal, Kabul Canal, and Lower Sawat were completed by the end of l9th century. However, at the time of independence country had 29 canals to provide regulated supply to an area of about 11 million hectares, beside an area of about 3.2 million hectares irrigated through inundation canals leading from Indus and its tributaries. These main inundation canals included Upper Sutlej, Lower Sutlej, Shahpur, and Chenab in Punjab; whereas, Rohri, Fuleli, Pinyari, and Kalri in Sindh. However, after the construction of barrages these canals are no more inundation canals but get regulated water supply and some of them have become perennial while few are nonperennial.

We have entered into 21st century with world's largest and unified irrigation system that consists of three major reservoirs (Chashma, Mangla, and Tarbela); 19 barrages (Ferozepur, Sulemanki, Islam, Balloki, Marala, Trimmu, Panjnad, Kalabagh, Sukkur, Kotri, Taunsa, Guddu, Chashma, Mailsi, Balloki, Sidhnai, Rasul, Qadirabad, and Marala); 12 link canals; 45 irrigation canals; and over 107,000 water courses and millions of farm channels & field ditches. The total length of main canal system is estimated about 585000 Kilometer (36932 miles) and that of watercourses & field channels exceeds 1.62 million Kilometers (over 1.02 million miles).

Surface water resources: Irrigated agriculture was, still is, and will remain in future the backbone of Pakistan's economy. Nature has blessed Pakistan with abundant surface and subsurface water resources. These resources had been exploited and utilized for agricultural, domestic, and industrial purposes in the past and will continue to be explored in future. The river Indus and its tributaries provide the surface water. At the time of independence, we had about 67 MAF water available for diversion, this amount increased to about 85 MAF by the year 1960. At this juncture, the right of three eastern rivers (Beas, Sutlej, and Ravi) was given to India under Irrigation Water Treaty 1960, during this period, Indus Basin Project (IBP) was implemented with international assistance of the Wold Bank. IBP enabled Pakistan to acquire significant capability of river flow regulation through integrated system. By the dint of river regulation-cum-storage facilities of IBP and other irrigation developments on the river Indus, canal diversions progressively increased and peaked to about 108 MAF. The recent statistical data shows that the River Indus and its tributaries provide about 147 MAF during flood season. Out of which nearly 106 MAF is diverted into canals and is available for agriculture, while, about 32 MAF outflows into sea, whereas, over 8.6 MAF is considered as evaporation and seepage losses in the river system. It is worth mention here that during last 3-5 years hardly 2-5 MAF water has flown into sea, whereas, at least 12 MAF must be left to sea in order to control intrusion of brackish water.

Ground water resources: The Indus plains constitute about 34 million hectares (over 85 million acres) of cultivable land, which is under-lain predominantly by sand alluvium to a considerable depth. Annual recharge to ground water system of this Indus plain is estimated around 55 MAF, out of which about 48 MAF is within the commands of Indus basin irrigation system (IBIS). Presently, 39 MAF is being extracted annually. Ground water is also found in some rain-fed (Barani) lands, and inter-mountain valleys at depths varying from 100 to 200 ft. During 1950s, large area in the Indus basin became waterlogged and soil salinity increased adversely affecting the agricultural productivity. It was the time when government got involved and took initiatives in the ground water development. The efforts began to control the twin menaces of waterlogging and salinity by the way of providing drainage facilities. Government embarked on a series of SCARPs in the late 1950s aimed at lowering the ground water table by providing "vertical drainage" through large capacity deep tube wells. Because of better economic returns, priority was given to locating SCARPs in the areas with ground water quality suitable for supplemental irrigation, making the drainage a by product in effect. During past four decades, about 15000 SCARP tube wells have been installed by the Government in 57 projects covering a gross area of about 7.7 million hectares affected land for putting it back into production. Almost 75% of all SCARP tube wells were installed in the Punjab. About 81% of total tube wells installed in Punjab province are located in fresh ground water areas, whereas, remaining 19% tube wells have been installed in saline ground water areas. The tube wells installed in the fresh ground water areas have been pumping water directly into watercourses; thus, they are being used for irrigation in addition to canal water. However, the tube wells installed in the areas with saline ground water, discharge saline water directly into drains, from where it is being disposed of.

Soon after the initiation of the SCARP program: Large-scale development of ground water was started by the private tube wells. According to latest reports issued by the Government of Pakistan, the number of private tube wells has increased from 27000 to over 400000 during period between 1964 and 1995. All of the 400000 private tube wells have been installed in fresh ground water zones and are being used for irrigation purposes. About 80 per cent of these tube wells are located in Punjab and supply around 40 per cent of total irrigation in the province.

Future of water resources and needs: One of the key issues to Pakistan is the growing population pressure, which is responsible for driving its water resource development. It has the world's fastest growing population that has surpassed the 140 million mark by now and is still increasing at an alarming rate of around 2.8%, which needs to be checked, whereas the growth rate in agriculture sector remains somehow lower than the demand due to limiting irrigation water. To keep up the pace of agricultural growth comparable to population growth, we must bring additional lands under cultivation. In order to achieve the required growth targets in agriculture, we will need estimated amounts of about 149 MAF by 2000, 215 MAF by year 2013 and about 277 MAF by year 2025. This scenario warns that Pakistan has already slid from water affluent country to a water scare country and already a shortage of over 40 MAF persists and it will increase to a projected water shortage of over 108 MAF, and 151 MAF by years 2013 and 2025, respectively. Since no additional water is available, it is better to improve the existing water system and land capabilities; otherwise, Pakistan will be facing acute shortages of food, fiber, and edible oils in near future. It is time to recognize our responsibilities and start taking steps in right direction. We must keep eye on the issues such as, inadequate management and inefficient operation of irrigation systems, poor water application & unequal water distribution, depletion of ground water resources, reduction in storage capacities of existing system, and wastage of summer river surpluses and slow agricultural growth.

Development potential and future strategies

Improve surface storage capacity: Future development of the country depends on water resources expansion and management. It has been recognized that more than 83 MAF water can be generated through various resources (See Table). These potential resources include; surface water 33 MAF, ground water 9 MAF, watercourse improvement 15 MAF, minor canals 5 MAF, and distributaries 21 MAF. According to a report of working group on water resources for the 7th five year plan (1987), no new storage have been created after the completion of Tarbela due to rising controversies over the construction of such reservoirs. Thus, it has become necessary to focus on small size irrigation schemes (storage on rivers). There is a need to construct small dams on rivers Indus, Jhelum, Chenab, and their small tributaries. The potential sites for these small reservoirs/dams need to be surveyed. However, some of these sites are located at "Sehwan-Manchar Lake, Chotiari depression, Hamal Lake, Skardu, Bunji, Kohala, Kunhar, Rohtas, Neelam Valley, Ambahar, Dhok Pathan, Dhok Abakki, and Thal Reservoir" those may be explored/utilized. The level of Mangla dam can also be raised to increase its storage capacity. Another option is to manage the existing irrigation system in a better way and undertake new schemes wherever possible.

Conjunctive use of ground water: Conjunctive use refers to the co-ordinate, combined, creative exploitation, and judicious use of ground water for sustained development. It deals with neither over extraction nor under extraction of the source. This option has technically and economically been considered as the most viable strategy in the past studies. But, the tragedy of this source is that the government has no effective control over the excessive pumping of ground water in some areas, hence, it has started to diminish in those areas. The ground water table has already started declining in 14 out of 45 canal commands. Due to over-exploitation of this resource, the sustainability of irrigated agriculture is facing a new threat in some of the canal commands in Punjab. This situation needs to be checked and addressed urgently. However, Indus Basin Irrigation System (IBIS) has a potential of around 48 MAF water within its commands and nearly 39 MAF of ground water is being extracted annually. This leaves with 9 MAF of water still available at this source. This amount could be extracted and utilized for irrigation purpose.

Increase the efficiency of existing system: The unchecked growth of population has increased pressure on land and water resources throughout the world; thus, it has become imperative to conserve our water supplies. New sources of supply are becoming scare and are unlikely to be constructed in the near future due to geopolitical reasons, naturally, the emphasis must be given on methods that can salvage the supplies already being lost within the irrigation system in the form of seepage. Several reports have shown that about 25 to 30% of the water is being lost in the conveyance system of the different countries of the world. A considerable amount of water is lost during its conveyance due to seepage in lengthy canals; lining of the system channels could reduce these losses. As reported by WAPDA, more than 5 MAF of irrigation water could be saved by lining the minor canals only, and additional amount of about 3.6 MAF could be saved by water course improvement (see, GOP, Sixth five year plan, 1983-88), this makes a total saving of over 8.6 MAF. However, due to financial constrains, it is not possible to line entire canal system thus, the portions with high potential of seepage and those located in the areas with high salt content could be lined, by doing so, not only huge quantities of irrigation water could be saved but also the risk of water logging and salinity could be reduced. This would result in saving of huge investments that otherwise are required for drainage projects. Also, the existing system requires development of new irrigation projects on non-perennial basis. It has been stemmed out in the Water Apportionment Accord (WAA) of 1991, that remodelling / construction of non-perennial canals should be taken, this would not only provide additional water for agriculture but also save a bulk amount (derived during monsoon) from flowing into sea. In this regard construction of Thar Canal in Sindh (non-perennial canal) should be undertaken to carry the additional water during monsoon season.

Water distribution: The proper management, efficient application, and uniform distribution of available water at farm-gate have remained major problems since the existence of the irrigation network. Increasing water demand, deferred maintenance, siltation of channel prism, excessive water by tampered outlets and illegal water extraction & theft all lead towards inequity in the system. It has even become increasingly significant over last two decades. There is inequity in distribution at all levels in the system. Inequity in water distribution between head and tail is of the order of between 20 to 50 %. The water is distributed amongst the farmers "as per turn system" on a watercourse and each farmer receives his share on the basis of the area owned by him. Each farmer is allotted a specified time period, in proportion to his land holdings. In other words, this system disregards the crop consumptive use, frequency, and timely application of irrigation water. The tail enders however, receive 10 to 12 % less share of water, because the allowance is based on the theoretical losses, whereas, the actual or operational losses are high due to silt deposits at the heads, grass growing on banks and in the beds, trees taking their toll of water, rodents, snakes and other insects having their abodes in the banks, variety of irregular cuts (nuccas) with borrow bits full of water, overtopping on banks, and seepage through bed. The present situation is that the head reaches are waterlogged and the tail enders do not have enough water to meet their minimum requirement which results in low crop yields. For maximizing crop production, this constraint in the system would have to be removed. Government should take measures to bring flexibility in the existing system to meet the crop water requirements. Similarly, outlets on a minor or distributary receive different amounts of water. Illegal pumping from canals and excessive losses add to the inequity in distribution. Also, due to poor operation and maintenance of irrigation systems, the water distribution is not equitable and reliable. This has shaken the confidence of tail users and has discouraged them to use nonwater inputs for increasing crop yields.

Due to shortage of water, the tail enders have been forced to use poor quality water without proper mixing, which has given birth to salinity in such areas. This problem could be overcome by lining the whole watercourse, again the investment becomes a constraint, it is not possible to line the whole or optimum length of the watercourses. The logical reaches need priority lining are the head sections where silt deposits and raises the bed level which reduces the flow of water, the sandy areas where the percolation losses are too high. The watercourse improvement, proper maintenance, and equal distribution would result in saving of more than 15 MAF of water.

Adoption of water conservation techniques: Water conservation can play an important role in sustaining agricultural development. This requires substantial improvements in water use efficiency, choice of suitable cropping pattern, growing water-efficient crops, and introducing modern irrigation application techniques (trickle. sprinkler etc.). It has been observed that once water reaches at the farm gate, then, it becomes the responsibility of farmer to use it. Farmers in Pakistan generally practice basin, border or furrow methods of irrigation but the application efficiency of these methods is very low and the water applied this way is not distributed uniformly on their fields. It is quite common to find a combination of over and under irrigation within a single field. Over and under irrigation conditions results in poor crop germination that causes yield reductions.

Recommendations: The unchecked growth of population has increased pressure on land and water resources throughout the world; thus, it has become imperative to conserve our water supplies. New sources are becoming scare and are unlikely to be constructed in the near future (except small dams) due to geo-political reasons, naturally, the emphasis must be given on methods that can salvage the supplies already being lost within the irrigation system in the form of seepage.

The second largest contribution to the total water availability comes from the ground water resources. This source has been exploited and very well utilized by the public SCARP and private tube wells. It can still provide over 9 MAF of water. This source could be exploited and judiciously used for irrigation purposes. However, in some areas groundwater is rapidly depleting due to excessive pumpage, government should take control in such areas to save them from depleting.

Water conservation programmes, such as, lining of minor canals. distributaries, and water courses should be accelerated, this would not only save the huge quantities of water, but would also help reduce problems of water logging and salinity in the country. Conjunctive use of water based on scientific lines should be encouraged. Efforts should be made to convert the present rotation-based-irrigation system to demand oriented system. Besides that, the modern irrigation application techniques (trickle, sprinkler etc.), that have potential to improve water distribution and water use efficiencies, should be introduced in the areas with water scarcity. Particularly, in Sindh province, for the development of Kohistan areas of Dadu and Karachi districts, such techniques would be beneficial, thus, may be initiated.

Since, improper management, poor operation and maintenance of irrigation systems, inefficient application, and inequitable distribution of available water at farm gate have remained major problems since the existence of the irrigation network. Increasing water demand, deferred maintenance, siltation of channel prism, excessive water by tampered outlets, and illegal water extraction all lead towards inequity in the system. Similarly, outlets on a minor or distributary receive different amounts of water. Thus, it is need of time that government should take appropriate measures to ensure equitable distribution, to stop illegal extraction, and to improve system efficiency. One way to over come these problems is to empower water users so that they can play effective role in managing the proper water supplies in their distributaries, minors, and watercourses. The past experiences show that irrigation department has failed to stop illegal theft and extraction thus irrigation distribution system needs to be privatized through water users associations. Also, irrigation water is supplied at negligible cost to irrigators that is why they do not treat water as a precious resource; therefore, there is a need to increase the water prices to make irrigators realize the importance of this asset.

Inspite of continuous efforts, the desired national targets have not been achieved. Low crop yields, decreasing fertility of lands, onslaught of water logging & salinity problems coupled with environmental degradation, improper water management, and miserable economic conditions of the farmers are the indicators that we have to work harder and go a long way to make improvements in agriculture sector through development and transfer of modern technologies of agricultural lands. However, to enhance optimum crop production per unit volume of water consumed, high yielding varieties should be introduced and better agronomic inputs (fertilizers and pesticides) should be applied on scientific basis. It is also recommended that the crops should be irrigated as per their requirements. The existing crop water requirements can theoretically be met by converting the existing irrigation system to crop consumptive use based system. This will allow water to be delivered at time of requirement and the amounts nearly matched to crop needs.

Farmer's organizations, water user associations, and private sector be involved in construction, operation, and maintenance of irrigation system. Such associations are conceived as a mechanism for creating a co-operative framework for improvement of watercourses.

Table. Scenario of water resources of the country

Surface water resources	**Annual water flow MAF**
Water available at canal head (1947)	67

Water available at canal head (1960)	85
Rim station flow (1997)	147
Water diverted to canals (1997)	106
Water flow to the sea (1997)	32
Losses in the river system	8.6
Ground water resources	MAF
Recharge to groundwater	55
Recharge to groundwater within canal command	48
Groundwater pumping	39

Water required in future			
Year	**Water required**	**Water available Surface + Ground**	**Shortage**
.	**MAF**	**MAF**	**MAF**
2000	149	109	40
2013	215	107	108
2025	277	126	151

Potential for water development per annum	
Water source	**MAF**
Surface water reservoir (Kalabagh, Basha, and Dassu)	17
Surface water reservoir (12 small dams sites proposed)	16
Water lost in canals and distributaries	21
Water lost in minors	5
Water lost in water courses	15
Groundwater	9

Sub-total	83

Agro-Ecological Regions of Pakistan

Basically,Pakistan has been divided into ten agro-ecological zones based on physiography, climate, land use and water availability.

Indus Delta

This zone extends from little south of Hyderabad to Arabian sea including Badin and Thatta.The mean monthly summer rainfall is 75 mm and winter rainfall less than 5 mm.

Southern Irrigated Plain

This represents lower indus plain in Sindh extending from Jacobabad to Dadu.The mean monthly summer rainfall is 18 mm in the north and 45 to 55 mm in the south.

Sandy Desert (a)

This zone includes vast sandy area of Thar-Cholistan.The maximum rainfall is 300 mm.

Sandy Desert (b)

This zone includes areas of Thal-Mianwali.The rainfall is between 300 and 350 mm.

Northern Irrigated Plain (a)

The area between two major rivers (doabs) of the Punjab (Jhelum and Sutlej) come under this zone.The mean annual rainfall is 300 to 500 mm in the east and 200 to 300 mm in the southwest.

Northern Irrigated Plain (b)

This zones includes alluvial valleys of Peshawar and Mardan. The mean monthly rainfall is 20 to 30 mm.

Barani Lands

It covers the salt range of Pothowar plateau and the himalyan piedmont plains, such as those of Attock, Rawalpindi, Bannu and Karak.In the North the mean monthly rainfall is 200 mm in summer and 35 to 50 mm in winter.The mean monthly rainfall is 85 mm in summer and 30 to 45 mm in winter.

Wet Mountains

This region contains high mountains as found in upper Hazara and Swat. The mean monthly rainfall is 235 mm in summer and 116 mm in winter.

Northern dry mountains

It includes Gilgit,Baltistan,Chitral and Dir valleys.The mean monthly rainfall is 25 to 75 mm in winter and 10 to 20 mm in summer.

Western dry mountains

This mountainous track extends from Bannu (NWFP) To Zhob, Pashin, Quetta and Kalat in Balochistan.Tribal area of Khurram and Waziristan area also fall in this zone.The mean monthly rainfall is 95 mm in summer and 63 to 95 mm in winter.

Dry Western Plateau

It extends from Chagai to the coastal area of Mekran.The mean monthly rainfall is 37 mm.

Sulaiman Piedmont

It extends from D.I Khan in NWFP to Dera Ghazi Khan in Punjab and Dera Bugti, Kachhi and Nasirabad in Balochistan.The mean monthly rainfall is less than 15 mm

Farming system

A farming system is an established way to operate a piece of land to raise crops, livestock or both and includes everything done on farm and outside the farm related to farm operations."

INTRODUCTION

A farming system is an established way to operate a piece of land to raise crops, livestock or both and includes everything done on farm and outside the farm related to farm operations.

CLASSIFICATION CRITERIA

The classification of farming systems is based on **2 main principles**;

(1) Available natural resources - includes land, water resources, climate, grazing areas etc.

(2) Dominant pattern of farm and household activities - such as crops, aquaculture, livestock, forestry, processing and off-farm activities etc.

There are many ways to categorize farming systems;

a) extensive and intensive farming systems

b) subsistence and commercial farming systems

c) dry and irrigated farming systems

d) individual and multiple farming systems

e) arable farming, livestock rearing and mixed farming

FACTORS INFLUENCING

THE CHOICE OF FARMING SYSTEMS IN PAKISTAN

1) SOIL - factors of soil including, texture, depth, slope, erosion, pH, fertility, mineral nutrients, alkalinity, salinity, acidity, drainage etc.

2) CLIMATE - temperature, precipitation, irrigation, solar radiations and photoperiod, humidity, winds, storms, air pollutants etc.

3) RESOURCES - factors like capital, labor, seed, fertilizers, inseticides, farm machinery, technology, storage facilities etc.

4) CAPABILITIES OF PLANTS AND ANIMALS - the genetic potentials and production of the selected animals and plants in relation to the selected place for setting up the farm

5) ECOLOGY - crops, pests, trees, animals, weeds, and diseases etc of the selected location for setting up the farm.

6) SOCIAL, POLITICAL AND ECONOMIC FACTORS - markets, agro-based industry in vicinity, consumer choice, demand, farm inputs and output prices, transportation, etc.

KINDS OF FARMING SYSTEMS

There are many different types of farming systems in the world based upon the above described classification criteria. A few important kinds are briefed here;

i) ARABLE FARMING

Farming system which includes production of only crops in the field and the related farm operation of cultural practices, harvesting, storage, transportation and marketing. It includes many different types of cropping systems.

ii) LIVESTOCK FARMING (PASTORAL FARMING SYSTEM)

The rearing of animals at farm for production of meat, milk and eggs and related farm operation of management like purchase of farm inputs, vaccination schemes and transport of the products to the market.

iii) POULTRY FARMING

The raising of chicken for meat and egg production in farms and associated management operations.

iv) INTENSIVE FARMING

In this system multiple cropping system and raising of more livestock is carried out at the same time in one calender year in order to get maximum output from the land and labour resources. There is efficient utilization of solar energy and available resources at the farm to get the maximum yield.

v) EXTENSIVE FARMING

In this system extensive land is used for the farming, with minimum expenditure of on attention to efficient use of the other resources. Yields per unit area of land are usually low. The purpose of such farming system is to get the maximum output from the scarce resource e.g., water, labour, fertilizer.

vi) DIVERSIFIED FARMING

In this system a wide spectrum of crops are cultivated and many different types of animals are raised.

vii) SUBSISTENCE FARMING

The farming system the basic objective is to fulfil the requirements of food, clothing and shelter of the farming family. It is common in developing countries due to small land holdings of the farmers.

viii) COMMERCIAL FARMING

The farming system in which objective is commercial scale production of farm products including crop and livestock products (milk, meat, eggs).

ix) TRUCK FARMING

The objective of such farming system is to produce one or two main types of crops or livestock to transport the products to the nearby markets or agro-based industry. The products are produced in bulk and marketed.

x) DRY / RAINFED FARMING

Farming system in which crop cultivation and rearing of livestock is carried out in areas with low rainfall and no irrigation facilities. The yields are largely affected by water availability. The objective of such system is to conserve moisture and get maximum possible income and output from the available rainfall or water.

xi) URBAN BASED FARMING SYSTEM

In large towns and cities, intensive production of perishable high value commodities such as fresh vegetables is being carried out. This is a commercial system with high levels of inputs (fertilizers, pesticides etc.) and links to the both rural and urban areas.

xii) ARID FARMING SYSTEM

This system depends on irrigation water for raising of crops and rearing of animals in the farm. This system in Pakistan is dependant upon the large and diverse canal system of Indus rivers and its tributires which irrigate vastness of plains of Punjab, Khyber Pakhtunkhwa, Sindh and small area of Balochistan.

xiii) OTHER FARMING SYSTEMS IN PAKISTAN

There are numerous other examples of farming systems like;

a) Agri-pastoral farming system (crops + livestock farming)

b) Fruit Farming (orchards)

c) Mountain Farming (contour plantations)

d) Grassland Farming (fodder production for livestock farming)

e) Fish Farming (raising of fish and associated farm enterprises) etc.

TILLAGE

DEFINATION:

"Tillage is defined as, the mechanical manipulation of the soil aimed at improving its physical condition or **tilth."**

Tillage can also be described as the practice of modifying the state of soil in order to provide conditions favorable to crop growth.

Tillage can also be defined as, the physical manipulation of soil, and it is intended to destroy weeds, incorporate crop residues and amendments into soil, increase infiltration and reduce evaporation, prepare seedbed and break hard layers to facilitate root penetration.

In general, tillage is a group of field operations carried out in the process of field crop production, the main purpose of which is to increase crop yield and to prevent yield or economic losses by reducing the costs of production. Tillage practices differ from one area to another depending upon soil type, cropping pattern, soil moisture (rainfed), and climatic factor.

AIMS OF TILLAGE:

1. Production of a suitable tilth, or soil structure.
2. Control of weeds
3. Control of soil moisture
4. Incorporation of organic matter (manures and fertilizers), and agrochemicals for weed and pest control.

Objectives of tillage:
There are several major objectives of tillage.

1. Improve soil tilth and prepare a seedbed.
2. Manipulate plant residues and farm wastes.
3. Manage water and air in the soil.
4. Control weeds and soil borne insect pests and diseases.
5. Establish a surface layer which prevents wind and soil erosion.

These are discussed below:

PREPARATION OF SEEDBED:

The desirable characteristics of a seed bed are:
1. Weed-free soil, which prevents the loss of precious water and plant nutrients to weeds.
2. Granular soil structure, which allows close contact of the seed and the plant roots with soil particles. It also facilitates penetration of air and water. Different soil types require different management to produce a seedbed of desirable tilth.
3. Soil free of compacted layers, which reduce air and water penetration and inhibit root development.
4. Generally level soil surface which facilitates planting seeds at a uniform depth and is especially important for proper water management in irrigated areas.

There are many methods of seedbed preparation. As the number of acres farmed by one person and the cropping intensity increase, there is an increasing demand for more efficient tillage management.

MANIPULATION OF PLANT RESIDUES AND FARM WASTES:

In some areas virtually all of the plant residues such as straw, stubble, fodder, and even roots are utilized for animal feed and fuel. However, with some crops there is a good deal of crop residue left in the field which, if buried in the soil, can increase its organic matter content.
Incorporation of organic matter into the soil results in:
(a) Increased soil infertility.
(b) Increased water penetration and water-holding capacity.
(c) Enhanced soil microbial activities.
However, the problem of how and when to handle crop residues must be addressed.

Decaying organic matter ties up the soil nitrogen supply for sometime, so a small quantity of chemical nitrogen fertilizer should be added to the soil. The presence of straw or crop residue causes mechanical problems in the irrigated areas, especially in cereal farming, as the straw and stubble clog the tillage implements and seedling drills. In rainfed areas, however, leaving some straw in the field as straw mulch is desirable for conserving soil moisture and preventing wind and water erosion.

MANAGING WATER IN THE SOIL:

Tillage practices vary widely depending on the soil type, climatic regions, and crops. In irrigated areas tillage operations are mainly directed at destroying weeds, stubble, and systems of previous crops and improving the physical condition of the soil for proper seedbed preparation. Tillage plays an important role in irrigated areas. Field must be level and smooth with proper slope and drainage. Sometimes beds are prepared for growing various crops; this allows for both irrigation and drainage.

In areas of low rainfall, and where crops are produced under rainfed conditions, the main need is to conserve soil moisture and reduce evaporation and soil erosion. In semiarid areas of Pakistan, water management is critical. Limited moisture for crop growth is often the major limiting factor for crop yields. Successful tillage systems and practices have recently been developed specifically for proper moisture conservation in the rainfed areas and a large array of tillage implements has been tested.

Farmer of the barani areas normally do 8-10 shallow ploughings with a cultivator for moisture conservation of rainwater. But instead of rain moisture conservation, these excessive shallow ploughings cause compaction, and a hardpan is developed, they not only restrict water infiltration deep into the soil profile, but also restrict the penetrating roots searching for moisture and nutrients. Thus crop growth and development are affected. One deep ploughing with a mouldboard plough before the onset of the summer monsoon rains as primary tillage, and two ploughings with a cultivator along with planking just before the end of monsoon rains are the best tillage systems for better moisture conservation. This system is also effective for termite and weed control for the coming rabi season crops such as wheat, barley, lentil, and chickpea. Since dryland farming often involves large areas of open land, this is the area where large machines are most efficiently used.

CONTROLLING WEEDS:

For many centuries, little was done to control or eliminate weeds. A lot of backbreaking manual labor was developed to weed control but with little success. Nowdays, with the use of mechanical tillage practices, weeds can be controlled effectively and economically. However, chemical weed control through various herbicides is also being practiced successfully.

PREVENTING WIND AND WATER EROSION:

Since the semiarid lands are rainfed areas and are often subject to wind and water erosion, an acceptable and appropriate tillage system must provide for soil erosion prevention and control. For example, one mouldboard ploughing with planking followed by two ploughings with a cultivator and planking will create rough soil surfaces containing clods from .5-5 cm which will help control both wind and water erosion. The excessive ploughings done by barani farmers will destroy the soil structure resulting in soil and water erosion.

EFFECT OF TILLAGE ON SOIL CONDITIONS:

Some of the main effects of tillage are discussed in the following paragraphs :

EFFECT ON SOIL MOISTURE:

Tillage practices and systems have been developed to facilitate water penetration into the soil and increase the amount of water retained for crop use later. The higher moisture content with the mouldboard plough indicates that better water infiltration deeper into the soil profile resulted from loosening of the compact layer. This tillage method is preferable to continous shallow ploughing with a cultivator.

It is unfortunate that many farmers either do not understand the concept of moisture conservation and tillage and its importance, or they do not have the equipment required to do the job properly. Excessive shallow tillage operations result in increased soil compaction which restrict root growth, impedes air exchange, and also create problems in soil drainage.

The soil contains not more but less water, and its physical structure is broken down. This prevents water infiltration and encourages soil erosion.

SOIL WATER RETENTION:

The pore size distribution resulting from loosening the soil effects its ability to retain moisture against applied suction as well as its water transmission characteristics. Tillage also affects soil water retention by changing surface tension, infiltration and redistribution, and evaporation of water from soil. However, the direction, duration, and the magnitude of effect depends upon pre-tillage operations and climatic conditions.

The rough soil surface and depressions caused by tillage decrease runoff. Retention of rainwater in surface depressions increases the time available for water to percolate into the soil and, thus, water intake into the soil. This results in storing part of the rainwater in the soil profile. The nature and magnitude of soil surface roughness differs with soil type, implement used, the number of ploughing passes, and the moisture status at which the tillage operations are performed. The effectiveness of the rough surface also depends on the intensity and the amount of precipitation and the stability of soil aggregates. Soil with less stable aggregates on the surface is readily dispersed by high intensity rains, which reduces infiltration and increase runoff and potential soil loss.

INFILTRATION:

Apart from prolonged retention in depressions, tillage also enhances infiltrations of water if large voids are produced in a soil layer that is impeding infiltration, and if these voids are maintained for sufficient time. Tillage must penetrate the limiting layer completely, otherwise only surface storage is increased. Hendreson (1979) stated that the major factor determining the effect of tillage in infiltration was the structural stability of soil. In structurally unstable soils, the surface layer that slakes repeatedly under wetting and drying becomes relatively impervious, limiting infiltration.

EFFECT ON SOIL STRUCTURE:

Tillage directly affects the roughness and bulk density of the soil. These factors in turn directly affect water infiltration, crusting, and compaction, which in turn affect seedling emergence, root development, and nutrient uptake. The immediate effect of tillage is to loosen the soil and decrease its bulk density. Different tillage practices produce different bulk densities, and alteration in the bulk density of soil changes its porosity, inter-particle contact, and volume of water content. Changes in bulk density changes the fraction of all three soil components, (mineral matter, organic matter, and water)

EFFECT ON SOIL TEMPERATURE:

Research has shown that different tillage practices result in differences in soil temperature. For example, straw or stubble mulch usually decreases soil temperature. This may be advantage in the fall season, allowing earlier seeding and promoting profuse tillering of wheat and barley. In the spring, however, it may be disadvantage when seeding would be delayed or when the growth of fall-seeded crops would be retarded.

EFFECT ON EVAPORATION:

Evaporation from the soil is a major pathway of water loss created by tillage. Surface roughness caused by loosening of the upper soil layer by tillage increases the area of soil exposed to the atmosphere and allows greater penetration of wind. This results in increased evaporation from tilled compared with untilled soil. Soil mulch and straw mulch tillage systems reduce these evaporation looses, which is extremely important in rainfed agriculture.

EFFECT ON SOIL NUTRIENT UPTAKE:

Nitrogen (N) is probably the nutrient most affected by tillage, although both phosphorus (P) and potassium (K) are also influenced. Incorporation of organic matter and changes in the amount and location of soil water are the factors that cause most of the fluctuation in nutrient levels. The tillage effect can either be positive or negative for a given time and set of agro-climate conditions. Warm moist soil has greater microorganism activity, which result in greater mineralization on N, and in turn result in its higher uptake by plants (Standford et al.1973).

TILLAGE IMPLEMENTS

A variety of tillage implements are used to weaken soil strength, reduce compaction, and allow the free movement of air and water in order to promote plant growth. A wide array of different tillage implements are used in the country for primary tillage and seedbed preparation and for crops. These tillage implements range from the light animal-drawn desi plough to heavy implement drawn by high -powered tractors. Different tillage implements have been designed and are used for various operations depending on the kind of soil types of cropping, and agro-climatic conditions. These include the mouldboard plough, disc plough ,disc harrow, chisel, subsoiler, practices. The farmer has to consider both energy requirement and tilth conditions all the tillage implements are of great importance when considering their effects on crops production.

SEED

A **seed** is a small embryonic plant enclosed in a covering called the seed coat, usually with some stored food. It is the product of the ripened ovule of gymnosperm and angiosperm plants which occurs after fertilization and some growth within the mother plant. The formation of the seed completes the process of reproduction in seed plants (started with the development of flowers and pollination), with the embryo developed from the zygote and the seed coat from the integuments of the ovule. All seeds are different size, shape and color.

Seeds have been an important development in the reproduction and spread of flowering plants, relative to more primitive plants such as mosses, ferns and liverworts, which do not have seeds and use other means to propagate themselves. This can be seen by the success of seed plants (both gymnosperms and angiosperms) in dominating biological niches on land, from forests to grasslands both in hot and cold climates.

The term "seed" also has a general meaning that antedates the above—anything that can be sown, e.g. "seed" potatoes, "seeds" of cornor sunflower "seeds". In the case of sunflower and corn "seeds", what is sown is the seed enclosed in a shell or husk, whereas the potato is a tuber.

A typical seed includes three basic parts: (1) an embryo, (2) a supply of nutrients for the embryo, and (3) a seed coat.

The embryo is an immature plant from which a new plant will grow under proper conditions. The embryo has one cotyledon or seed leaf in monocotyledons, two cotyledons in almost all dicotyledons and two or more in gymnosperms. The radicle is the embryonic root. The plumule is the embryonic shoot. The embryonic stem above the point of attachment of the cotyledon(s) is the epicotyl. The embryonic stem below the point of attachment is the hypocotyl.

Within the seed, there usually is a store of nutrients for the seedling that will grow from the embryo. The form of the stored nutrition varies depending on the kind of plant. In angiosperms, the stored food begins as a tissue called the endosperm, which is derived from the parent plant via double fertilization. The usually triploid endosperm is rich in oil or starch, and protein. In gymnosperms, such as conifers, the food storage tissue (also called endosperm) is part of the female gametophyte, a haploid tissue. In some species, the embryo is embedded in the endosperm or female gametophyte, which the seedling will use upon germination. In others, the endosperm is absorbed by the embryo as the latter grows within the developing seed, and the cotyledons of the embryo become filled with this stored food. At maturity, seeds of these species have no endosperm and are termed exalbuminous seeds. Some exalbuminous seeds are bean, pea, oak, walnut, squash, sunflower, and radish. Seeds with an endosperm at maturity are termed albuminous seeds. Most monocots (e.g. grasses and palms) and many dicots (e.g. Brazil nut and castor bean) have albuminous seeds. All gymnosperm seeds are albuminous.

The seed coat (the testa) develops from the tissue, the integument, originally surrounding the ovule. The seed coat in the mature seed can be a paper-thin layer (e.g. peanut) or something more substantial (e.g. thick and hard in honey locust and coconut, or fleshy as in the sarcotesta of pomegranate). The seed coat helps protect the embryo from mechanical injury and from drying out.

In addition to the three basic seed parts, some seeds have an appendage on the seed coat such an aril (as in yew and nutmeg) or an elaiosome (as in Corydalis) or hairs (as in cotton). A scar also may remain on the seed coat, called the hilum, where the seed was attached to the ovary wall by the funiculus.

Kinds of seeds

Many structures commonly referred to as "seeds" are actually dry fruits. Sunflower seeds are sold commercially while still enclosed within the hard wall of the fruit, which must be split open to reach the seed. Different groups of plants have other modifications, the so-called stone fruits (such as the peach) have a hardened fruit layer (the endocarp) fused to and surrounding the actual seed. Nuts are the one-seeded, hard-shelled fruit of some plants with an indehiscent seed, such as an acorn or hazelnut.

Seed production

Immature elm seeds

Seeds are produced in several related groups of plants, and their manner of production distinguishes the angiosperms ("enclosed seeds") from the gymnosperms ("naked seeds"). Angiosperm seeds are produced in a hard or fleshy structure called a fruit that encloses the seeds, hence the name. (Some fruits have layers of both hard and fleshy material). In gymnosperms, no special structure develops to enclose the seeds, which begin their development "naked" on the bracts of cones. However, the seeds do become covered by the cone scales as they develop in some species of conifer.
Seed production in natural plant populations vary widely from year-to-year in response to weather variables, insects and diseases, and internal cycles within the plants themselves. Over a 20-year period, for example, forests composed of loblolly pine and shortleaf pine produced from 0 to nearly 5 million sound pine seeds per hectare. Over this period, there were six bumper, five poor, and nine good seed crops, when evaluated in regard to producing adequate seedlings for natural forest reproduction.

1) Endosperm; 2) Zygote; 3) Embryo; 4) Suspensor; 5) Cotyledons; 6) Shoot Apical Meristem; 7) Root Apical Meristem; 8) Radicle; 9) Hypocotyl; 10) Epicotyl; 11) Seed Coat

The inside of a Ginkgo seed, showing a well-developed embryo, nutritive tissue (megagametophyte), and a bit of the surrounding seed coat

Diagram of the internal structure of a dicot seed and embryo: (a) seed coat, (b) endosperm, (c) cotyledon, (d) hypocotyl
The seed, which is an embryo with two points of growth (one of which forms the stem, the other the roots) is enclosed in a seed coat with some food reserves.
Angiosperm seeds consist of three genetically distinct constituents: (1) the embryo formed from the zygote, (2) the endosperm, which is normally triploid, (3) the seed coat from tissue derived from the maternal tissue of the ovule. In angiosperms, the process of seed development begins with double fertilization and involves the fusion of the egg and sperm nuclei into a zygote. The second part of this process is the fusion of the polar nuclei with a second sperm cell nucleus, thus forming a primary endosperm. Right after fertilization, the zygote is mostly inactive, but the primary endosperm divides rapidly to form the endosperm tissue. This tissue becomes the food the young plant will consume until the roots have developed after germination. The seed coat forms from the two integuments or outer layers of cells of the ovule, which derive from tissue from the mother plant, the inner integument forms the tegmen and the outer forms the testa. When the seed coat forms from only one layer, it is also called the testa, though not all such testae are homologous from one species to the next.
In gymnosperms, the two sperm cells transferred from the pollen do not develop seed by double fertilization, but one sperm nucleus unites with the egg nucleus and the other sperm is not used.

Sometimes each sperm fertilizes an egg cell and one zygote is then aborted or absorbed during early development. The seed is composed of the embryo (the result of fertilization) and tissue from the mother plant, which also form a cone around the seed in coniferous plants such as pine and spruce.

The ovules after fertilization develop into the seeds; the main parts of the ovule are the funicle; which attaches the ovule to the placenta, the nucellus; the main region of the ovule where the megagametophyte develops, the micropyle; a small pore or opening in the ovule where the pollen tube usually enters during the process of fertilization, and the chalaza; the base of the ovule opposite the micropyle, where integument and nucellus are joined together.

The shape of the ovules as they develop often affects the final shape of the seeds. Plants generally produce ovules of four shapes: the most common shape is called anatropous, with a curved shape. Orthotropous ovules are straight with all the parts of the ovule lined up in a long row producing an uncurved seed. Campylotropous ovules have a curved megagametophyte often giving the seed a tight "C" shape. The last ovule shape is called amphitropous, where the ovule is partly inverted and turned back 90 degrees on its stalk (the funiculus).

In the majority of flowering plants, the zygote's first division is transversely oriented in regards to the long axis, and this establishes the polarity of the embryo. The upper or chalazal pole becomes the main area of growth of the embryo, while the lower or micropylar pole produces the stalk-like suspensor that attaches to the micropyle. The suspensor absorbs and manufacturers nutrients from the endosperm that are used during the embryo's growth.

The embryo is composed of different parts; the epicotyl will grow into the shoot, the radicle grows into the primary root, the hypocotyl connects the epicotyle and the radicle, the cotyledons form the seed leaves. Monocotyledonous plants have other structures; instead of the hypocotyle-epicotyle, it has a coleoptile that forms the first leaf and connects to the coleorhiza that connects to the primary root and adventitious roots form from the sides. The seeds of corn are constructed with these structures; pericarp, scutellum (single large cotyledon) that absorbs nutrients from the endosperm, endosperm, plumule, radicle, coleoptile and coleorhiza—these last two structures are sheath-like and enclose the plumule and radicle, acting as a protective covering. The testae or seed coats of both monocots and dicots are often marked with patterns and textured markings, or have wings or tufts of hair.

Seed size and seed set.

A collection of various vegetable and herb seeds

Seeds are very diverse in size. The dust-like orchid seeds are the smallest, with about one million seeds per gram; they are often embryonic seeds with immature embryos and no significant energy reserves. Orchids and a few other groups of plants are mycoheterotrophs which depend on mycorrhizal fungi for nutrition during germination and the early growth of the seedling. Some terrestrial orchid seedlings, in fact, spend the first few years of their lives deriving energy from the fungi and do not produce green leaves. At over 20 kg, the largest seed is the coco de mer.

Plants that produce smaller seeds can generate many more seeds per flower, while plants with larger seeds invest more resources into those seeds and normally produce fewer seeds. Small seeds are quicker to ripen and can be dispersed sooner, so fall blooming plants often have small seeds. Many annual plants produce great quantities of smaller seeds; this helps to ensure at least a few will end in a favorable place for growth. Herbaceous perennials and woody plants often have larger seeds; they can produce seeds over many years, and larger seeds have more energy reserves for germination and seedling growth and produce larger, more established seedlings after germination.

Seed functions

Seeds serve several functions for the plants that produce them. Key among these functions are nourishment of the embryo, dispersal to a new location, and dormancy during unfavorable conditions. Seeds fundamentally are means of reproduction, and most seeds are the product of sexual reproduction which produces a remixing of genetic material and phenotype variability on which natural selection acts.

Embryo nourishment

Seeds protect and nourish the embryo or young plant. They usually give a seedling a faster start than a sporeling from a spore, because of the larger food reserves in the seed and the multicellularity of the enclosed embryo.

Seed dispersal

Unlike animals, plants are limited in their ability to seek out favorable conditions for life and growth. As a result, plants have evolved many ways to disperse their offspring by dispersing their seeds (see also vegetative reproduction). A seed must somehow "arrive" at a location and be there at a time favorable for germination and growth. When the fruits open and release their seeds in a regular way, it is called dehiscent, which is often distinctive for related groups of plants; these fruits include capsules, follicles, legumes, silicles and siliques. When fruits do not open and release their seeds in a regular fashion, they are called indehiscent, which include the fruits achenes, caryopsis, nuts, samaras, and utricles.

Seed dispersal is seen most obviously in fruits; however, many seeds aid in their own dispersal. Some kinds of seeds are dispersed while still inside a fruit or cone, which later opens or disintegrates to release the seeds. Other seeds are expelled or released from the fruit prior to dispersal. For example, milkweeds produce a fruit type, known as a follicle, that splits open along one side to release the seeds. Iris capsules split into three "valves" to release their seeds.

By wind (anemochory)

Dandelion seeds are contained within achenes, which can be carried long distances by the wind.

The seed pod of milkweed (Asclepias syriaca)

Some seeds (e.g., pine) have a wing that aids in wind dispersal.

The dustlike seeds of orchids are carried efficiently by the wind.
Some seeds, (e.g. milkweed, poplar) have hairs that aid in wind dispersal.
Other seeds are enclosed in fruit structures that aid wind dispersal in similar ways:
Dandelion achenes have hairs.
Maple samaras have two wings.

By water (hydrochory)

Some plants, such as Mucuna and Dioclea, produce buoyant seeds termed sea-beans or drift seeds because they float in rivers to the oceans and wash up on beaches.

By animals (zoochory)

Seeds (burrs) with barbs or hooks (e.g. acaena, burdock, dock) which attach to animal fur or feathers, and then drop off later.

Seeds with a fleshy covering (e.g. apple, cherry, juniper) are eaten by animals (birds, mammals, reptiles, fish) which then disperse these seeds in their droppings.

Seeds (nuts) are attractive long-term storable food resources for animals (e.g. acorns, hazelnut, walnut); the seeds are stored some distance from the parent plant, and some escape being eaten if the animal forgets them.

Myrmecochory is the dispersal of seeds by ants. Foraging ants disperse seeds which have appendages called elaiosomes (e.g. bloodroot, trilliums, Acacias, and many species of Proteaceae). Elaiosomes are soft, fleshy structures that contain nutrients for animals that eat them. The ants carry such seeds back to their nest, where the elaiosomes are eaten. The remainder of the seed, which is hard and inedible to the ants, then germinates either within the nest or at a removal site where the seed has been discarded by the ants.This dispersal relationship is an example of mutualism, since the plants depend upon the ants to disperse seeds, while the ants depend upon the plants seeds for food. As a result, a drop in numbers of one partner can reduce success of the other. In South Africa, the Argentine ant (Linepithema humile) has invaded and displaced native species of ants. Unlike the native ant species, Argentine ants do not collect the seeds of Mimetes cucullatus or eat the elaiosomes. In areas where these ants have invaded, the numbers of Mimetes seedlings have dropped.

Seed dormancy

Seed dormancy has two main functions: the first is synchronizing germination with the optimal conditions for survival of the resulting seedling; the second is spreading germination of a batch of seeds over time so a catastrophe after germination (e.g. late frosts, drought, herbivory) does not result in the death of all offspring of a plant (bet-hedging). Seed dormancy is defined as a seed failing to germinate under environmental conditions optimal for germination, normally when the environment is at a suitable temperature with proper soil moisture. This true dormancy or innate dormancy is therefore caused by conditions within the seed that prevent germination. Thus dormancy is a state of the seed, not of the environment. Induced dormancy, enforced dormancy or seed quiescence occurs when a seed fails to germinate because the external environmental conditions are inappropriate for germination, mostly in response to conditions being too dark or light, too cold or hot, or too dry.

Seed dormancy is not the same as seed persistence in the soil or on the plant, though even in scientific publications dormancy and persistence are often confused or used as synonyms.

Often, seed dormancy is divided into four major categories: exogenous; endogenous; combinational; and secondary. A more recent system distinguishes five classes: morphological, physiological, morphophysiological, physical and combinational dormancy.

Exogenous dormancy is caused by conditions outside the embryo, including:

Physical dormancy or hard seed coats occurs when seeds are impermeable to water. At dormancy break, a specialized structure, the 'water gap', is disrupted in response to environmental cues, especially temperature, so water can enter the seed and germination can occur. Plant families where physical dormancy occurs include Anacardiaceae, Cannaceae, Convulvulaceae, Fabaceae and Malvaceae.

Chemical dormancy considers species that lack physiological dormancy, but where a chemical prevents germination. This chemical can be leached out of the seed by rainwater or snow melt or be deactivated somehow. Leaching of chemical inhibitors from the seed by rain water is often cited as an important cause of dormancy release in seeds of desert plants, but little evidence exists to support this claim.

Endogenous dormancy is caused by conditions within the embryo itself, including:

In morphological dormancy, germination is prevented due to morphological characteristics of the embryo. In some species, the embryo is just a mass of cells when seeds are dispersed; it is not differentiated. Before germination can take place, both differentiation and growth of the embryo have to occur. In other species, the embryo is differentiated but not fully grown (underdeveloped) at dispersal, and embryo growth up to a species specific length is required before germination can occur. Examples of plant families where morphological dormancy occurs are Apiaceae, Cycadaceae, Liliaceae, Magnoliaceae and Ranunculaceae.

Morphophysiological dormancy includes seeds with underdeveloped embryos, and also have physiological components to dormancy. These seeds, therefore, require a dormancy-breaking treatments, as well as a period of time to develop fully grown embryos. Plant families where morphophysiological dormancy occurs include Apiaceae, Aquifoliaceae, Liliaceae, Magnoliaceae, Papaveraceae and Ranunculaceae. Some plants with morphophysiological dormancy, such as Asarum or Trillium species, have multiple types of dormancy, one affects radicle (root) growth, while the other affects plumule (shoot) growth. The terms "double dormancy" and "two-year seeds" are used for species whose seeds need two years to complete germination or at least two winters and one summer. Dormancy of the radicle (seedling root) is broken during the first winter after dispersal while dormancy of the shoot bud is broken during the second winter.

Physiological dormancy means the embryo, due to physiological causes, cannot generate enough power to break through the seed coat, endosperm or other covering structures. Dormancy is typically broken at cool wet, warm wet or warm dry conditions. Abscisic acid is usually the growth inhibitor in seeds, and its production can be affected by light.

Drying, in some plants, including a number of grasses and those from seasonally arid regions, is needed before they will germinate. The seeds are released, but need to have a lower moisture content before germination can begin. If the seeds remain moist after dispersal, germination can be delayed for many months or even years. Many herbaceous plants from temperate climate zones have physiological dormancy that disappears with drying of the seeds. Other species will germinate after dispersal only under very narrow temperature ranges, but as the seeds dry, they are able to germinate over a wider temperature range.

In seeds with combinational dormancy, the seed or fruit coat is impermeable to water and the embryo has physiological dormancy. Depending on the species, physical dormancy can be broken before or after physiological dormancy is broken.

Secondary dormancy is caused by conditions after the seed has been dispersed and occurs in some seeds when nondormant seed is exposed to conditions that are not favorable to germination, very often high temperatures. The mechanisms of secondary dormancy are not yet fully understood, but might involve the loss of sensitivity in receptors in the plasma membrane.

The following types of seed dormancy do not involve seed dormancy, strictly speaking, as lack of germination is prevented by the environment, not by characteristics of the seed itself (see Germination):

Photodormancy or light sensitivity affects germination of some seeds. These photoblastic seeds need a period of darkness or light to germinate. In species with thin seed coats, light may be able to penetrate into the dormant embryo. The presence of light or the absence of light may trigger the germination process, inhibiting germination in some seeds buried too deeply or in others not buried in the soil.

Thermodormancy is seed sensitivity to heat or cold. Some seeds, including cocklebur and amaranth, germinate only at high temperatures (30°C or 86°F); many plants that have seeds that germinate in early to midsummer have thermodormancy, so germinate only when the soil temperature is warm. Other seeds need cool soils to germinate, while others, such as celery, are inhibited when soil temperatures are too warm. Often, thermodormancy requirements disappear as the seed ages or dries.

Not all seeds undergo a period of dormancy. Seeds of some mangroves are viviparous; they begin to germinate while still attached to the parent. The large, heavy root allows the seed to penetrate into the ground when it falls. Many garden plant seeds will germinate readily as soon as they have water and are warm enough; though their wild ancestors may have had dormancy, these cultivated plants lack it. After many generations of selective pressure by plant breeders and gardeners, dormancy has been selected out.

For annuals, seeds are a way for the species to survive dry or cold seasons. Ephemeral plants are usually annuals that can go from seed to seed in as few as six weeks.

Seed persistence and seed banks

Further information: Seed hibernation

Seed germination

Germinating sunflower seedlings.

Seed germination is a process by which a seed embryo develops into a seedling. It involves the reactivation of the metabolic pathways that lead to growth and the emergence of the radicle or seed root and plumule or shoot. The emergence of the seedling above the soil surface is the next phase of the plant's growth and is called seedling establishment.

Three fundamental conditions must exist before germination can occur. (1) The embryo must be alive, called seed viability. (2) Any dormancy requirements that prevent germination must be overcome. (3) The proper environmental conditions must exist for germination.

Seed viability is the ability of the embryo to germinate and is affected by a number of different conditions. Some plants do not produce seeds that have functional complete embryos, or the seed may have no embryo at all, often called empty seeds. Predators and pathogens can damage or kill the seed while it is still in the fruit or after it is dispersed. Environmental conditions like flooding or heat can kill the seed before or during germination. The age of the seed affects its health and germination ability: since the seed has a living embryo, over time cells die and cannot be replaced. Some seeds can live for a long time before germination, while others can only survive for a short period after dispersal before they die.

Seed vigor is a measure of the quality of seed, and involves the viability of the seed, the germination percentage, germination rate and the strength of the seedlings produced.

The germination percentage is simply the proportion of seeds that germinate from all seeds subject to the right conditions for growth. The germination rate is the length of time it takes for the seeds to germinate. Germination percentages and rates are affected by seed viability, dormancy and environmental effects that impact on the seed and seedling. In agriculture and horticulture quality seeds have high viability, measured by germination percentage plus the rate of germination. This is given as a percent of germination over a certain amount of time, 90% germination in 20 days, for example. 'Dormancy' is covered above; many plants produce seeds with varying degrees of dormancy, and different seeds from the same fruit can have different degrees of dormancy. It's possible to have seeds with no dormancy if they are dispersed right away and do not dry (if the seeds dry they go into physiological dormancy). There is great variation amongst plants and a dormant seed is still a viable seed even though the germination rate might be very low.

Environmental conditions effecting seed germination include; water, oxygen, temperature and light.

Three distinct phases of seed germination occur: water imbibition; lag phase; and radicle emergence.

In order for the seed coat to split, the embryo must imbibe (soak up water), which causes it to swell, splitting the seed coat. However, the nature of the seed coat determines how rapidly water can penetrate and subsequently initiate germination. The rate of imbibition is dependent on the permeability of the seed coat, amount of water in the environment and the area of contact the seed has to the source of water. For some seeds, imbibing too much water too quickly can kill the seed. For some seeds, once water is imbibed the germination process cannot be stopped, and drying then becomes fatal. Other seeds can imbibe and lose water a few times without causing ill effects, but drying can cause secondary dormancy.

A number of different strategies are used by gardeners and horticulturists to break seed dormancy.

Scarification allows water and gases to penetrate into the seed; it includes methods to physically break the hard seed coats or soften them by chemicals, such as soaking in hot water or poking holes in the seed with a pin or rubbing them on sandpaper or cracking with a press or hammer. Soaking the seeds in solvents or acids is also effective for many seeds. Sometimes fruits are harvested while the seeds are still immature and the seed coat is not fully developed and sown right away before the seed coat become impermeable. Under natural conditions, seed coats are worn down by rodents chewing on the seed, the seeds rubbing against rocks (seeds are moved by the wind or water currents), by undergoing freezing and thawing of surface water, or passing through an animal's digestive tract. In the latter case, the seed coat protects the seed from digestion, while often weakening the seed coat such that the embryo is ready to sprout when it gets deposited (along with a bit of fertilizer) far from the parent plant. Microorganisms are often effective in breaking down hard seed coats and are sometimes used by people as a treatment; the seeds are stored in a moist warm sandy medium for several months under non sterile conditions.

Stratification, also called moist-chilling, breaks down physiological dormancy, and involves the addition of moisture to the seeds so they imbibe water, and they are then sublected to a period of moist chilling to after-ripen the embryo. Sowing outside in late summer and fall and allowing to over winter outside under cool conditions is an effective way to stratify seeds; some seeds respond more favorably to periods of oscillating temperatures which are part of the natural environment.

Leaching or the soaking in water removes chemical inhibitors in some seeds that prevent germination. Rain and melting snow naturally accomplish this task. For seeds planted in gardens, running water is best—if soaked in a container, 12 to 24 hours of soaking is sufficient. Soaking longer, especially in stagnant water, can result in oxygen starvation and seed death. Seeds with hard seed coats can be soaked in hot water to break open the impermeable cell layers that prevent water intake.

Other methods used to assist in the germination of seeds that have dormancy include prechilling, predrying, daily alternation of temperature, light exposure, potassium nitrate, the use of plant growth regulators, such as gibberellins, cytokinins, ethylene, thiourea, sodium hypochlorite, and others. Some seeds germinate best after a fire. For some seeds, fire cracks hard seed coats, while in others, chemical dormancy is broken in reaction to the presence of smoke. Liquid smoke is often used by gardeners to assist in the germination of these species.

Sterile seeds

Seeds may be sterile for few reasons: they may have been irradiated, unpollinated, cells lived past expectancy, or bred for the purpose.

Origin and evolution

The origin of seed plants is a problem that still remains unsolved. However, more and more data tends to place this origin in the middle Devonian. The description in 2004 of the proto-seed Runcaria heinzelinii in the Givetian of Belgium is an indication of that ancient origin of seed-plants. As with modern ferns, most land plants before this time reproduced by sending spores into the air, that would land and become whole new plants.
The first "true" seeds are described from the upper Devonian, which is probably the theater of their true first evolutionary radiation. The seed plants progressively became one of the major elements of nearly all ecosystems.

Economic importance

A variety of bean seeds.

Edible seeds

Further information: List of edible seeds

Many seeds are edible and the majority of human calories comes from seeds, especially from cereals, legumes and nuts. Seeds also provide most cooking oils, many beverages and spices and some important food additives. In different seeds the seed embryo or the endosperm dominates and provides most of the nutrients. The storage proteins of the embryo and endosperm differ in their amino acid content and physical properties. For example the gluten of wheat, important in providing the elastic property to bread dough is strictly an endosperm protein.
Seeds are used to propagate many crops such as cereals, legumes, forest trees, turfgrasses and pasture grasses. Particularly in developing countries, a major constraint faced is the inadequacy of the marketing channels to get the seed to poor farmers. Thus the use of farmer-retained seed remains quite common.
Seeds are also eaten by animals, and are fed to livestock. Many seeds are used as birdseed.

Poison and food safety

While some seeds are edible, others are harmful, poisonous or deadly. Plants and seeds often contain chemical compounds to discourage herbivores and seed predators. In some cases, these compounds simply taste bad (such as in mustard), but other compounds are toxic or break down into toxic compounds within the digestive system. Children, being smaller than adults, are more susceptible to poisoning by plants and seeds.
A deadly poison, ricin, comes from seeds of the castor bean. Reported lethal doses are anywhere from two to eight seeds,though only a few deaths have been reported when castor beans have been ingested by animals.
In addition, seeds containing amygdalin—apple, apricot, bitter almond, peach, plum, cherry, quince, and others—when consumed in sufficient amounts, may cause cyanide poisoning. Other seeds that contain poisons include annona, cotton, custard apple, datura, uncooked durian, golden chain, horse-chestnut, larkspur, locoweed, lychee, nectarine, rambutan, rosary pea, sour sop, sugar apple, wisteria, and yew. The seeds of the strychnine tree are also poisonous, containing the poison strychnine.
The seeds of many legumes, including the common bean (Phaseolus vulgaris), contain proteins called lectins which can cause gastric distress if the beans are eaten without cooking. The

common bean and many others, including the soybean, also contain trypsin inhibitors which interfere with the action of the digestive enzyme trypsin. Normal cooking processes degrade lectins and trypsin inhibitors to harmless forms.

Other uses

Cotton fiber grows attached to cotton plant seeds. Other seed fibers are from kapok and milkweed.

Many important nonfood oils are extracted from seeds. Linseed oil is used in paints. Oil from jojoba and crambe are similar to whale oil.

Seeds are the source of some medicines including castor oil, tea tree oil and the cancer drug, Laetrile.

Many seeds have been used as beads in necklaces and rosaries including Job's tears, Chinaberry, rosary pea, and castor bean. However, the latter three are also poisonous.

Other seed uses include:

Seeds once used as weights for balances.

Seeds used as toys by children, such as for the game Conkers.

Resin from Clusia rosea seeds used to caulk boats.

Nematicide from milkweed seeds.

Cottonseed meal used as animal feed and fertilizer.

Seed records

The massive fruit of the coco de mer.

The oldest viable carbon-14-dated seed that has grown into a plant was a Judean date palm seed about 2,000 years old, recovered from excavations at Herod the Great's palace on Masada in Israel. It was germinated in 2005. (A reported regeneration of Silene stenophylla (narrow-leafed campion) from material preserved for 31,800 years in the Siberian permafrost was achieved using fruit tissue, not seed.

The largest seed is produced by the coco de mer, or "double coconut palm", Lodoicea maldivica. The entire fruit may weigh up to 23 kilograms (50 pounds) and usually contains a single seed.

The earliest fossil seeds are around 365 million years old from the Late Devonian of West Virginia. The seeds are preserved immature ovules of the plant Elkinsia polymorpha.