A Text Book of

Farming System and Sustainable Agriculture

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up Universal Prakashan, Pune

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FEATURES

- Prepared by the well experienced authors
- As per the new syllabus of B.Sc. (Agri.) degree programme recommended by IV Deans committee
- As per the lesson plans and in simple language
- To meet students need for the preparation of M.Sc. Entrance Test, ICAR NET, JRF and various exams of State and Union Public Service Commission
- More comprehendible by citing examples, illustrations and figures, wherever necessary

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PREFACE

The developing countries in the world including India, where more than 60% population is depending upon agricultural and allied activities, are facing many problems in present and which may become more serious in future. More dependence upon monsoon rain, decreasing per head land holding, deterioration of natural resources (*viz.* land, water, air, etc.), natural calamities, global climate change are the major constraints in present agriculture. Fulfillment of food, fiber, fodder and fuel need of increasing population with struggling this problems as mentioned above, there is need to accept and adopt some changes to land utilization and farming technology.

With keeping this view in mind, the book "A Text Book of Farming System and Sustainable Agriculture" is the outcome of author's knowledge, understanding, research and work experience in agricultural field. The book contains detailed study of producing more income from less land and other resources in different regions and climate. The steps to fulfill food demands of increasing population without degradation of natural resources in sustainable manner are broadly discussed here through different chapters. The most burning issue of present condition 'Climate change and its relation to agriculture' is also discussed here with touching all the angels of it as- cause, effect, adoption and mitigation.

Authors has the confidence that the book is really useful for UG and PG students of agriculture for their regular academic syllabus as well as for the students who are appearing for different competitive examinations such as- M.Sc. Entrance Test, JRF, ICAR-NET, Agricultural Scientist Recruitment Board's examination and also for State and Union Public Service Commission's examination.

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CHAPTER - 1

Farming System - Concept and Scope

The Indian economy is predominantly rural and agriculture oriented. In agriculture, 85% of the holdings are less than two hectares and the declining trend in the average size of the farmer holdings, became as a serious problem. Majority of them are dry lands, which depend on erratic monsoon rains. The rest of the area is cultivated with supplemental irrigation. The farmers concentrate mainly on crop production, which is invariably subjected to a high degree of uncertainly income and employment.

In India the cultivable land is 143.8 million hectares and there is very little possibility of extending it further. Therefore, to meet the requirement of food grains for increasing population, the only option open is effective time and space utilization in agriculture. The time concept relates to increasing the intensity of cropping under assured irrigated conditions, whereas space utilization pertains to building up of vertical dimension through multi-tier cropping and farming system approach. Thus by making use of these time and space concept either in irrigated or in rainfed areas, the productivity per unit area per unit time can be substantially enhanced. Therefore the only way to increase an agricultural production in the small or marginal units of farming is to increase the productivity per unit time and per unit area. This may be achieved by early maturing varieties with equal yields or by improving techniques of culture, fertilizer use, weed and pest control.

Farm :

A farm is organized economic unit in which crop and animal production is carried out with purpose of producing economic net returns. It is an area of land, including various structures, devoted primarily to the practice of producing and managing food, fibers and fuel.

Farming :

The term farming covers a wide spectrum of agricultural production work. At one end of this spectrum is the subsistence farmer, who farms a small area with limited resource inputs, and produces only enough food to meet the needs of his family. At the other end is commercial intensive agriculture, including industrial agriculture. Such farming involves large fields and/or numbers of animals, large resource inputs (pesticides, fertilizers. etc.) and a high level of mechanization. These operations generally attempt to maximize financial income from grain, produce or livestock.

Farming is defined as the way in which the farm resources are allocated to the needs and priorities of the farmers in his local circumstances which includes - a) Agro climatic condition such as the quantity, distribution and reliability of rainfall, soil type, topography, temperature etc. and b) Economic and institutional circumstances like market opportunities, prices, institutional and infrastructure facilities and technology.

Farming is the process of harnessing solar energy in the form of economic plant and animal products.

System :

System implies a set of inter related practices or processes organized into a functional entity. A system consists of several components which depend on each other. In other words, system is defined as a set of elements or components that are inter- related and interacting among themselves.

Farming is a dynamic biological and open system with human or social involvement. Being primarily biological with a high degree of dependence on weather variables and changing socio-political environments; farming is inherently more risky than any other system.

Farming System Concept and Scope :

"Farming system" therefore designates a set of agricultural activities organized while preserving land productivity, environmental quality and maintaining desirable level of biological diversity and ecological stability. The emphasis is more on a system rather than on gross output.

In other words "farming system" is a resource management strategy to achieve economic and sustain agricultural production to meet diverse requirement of the farm household while preserving the resource base and maintaining high environmental quality. Farming system specially refers to a group combination of enterprises in which the products and or the byproducts of one enterprise serve as the inputs for production of other enterprise.

Definition :

Farming system is a decision making unit comprising the farm household, cropping and livestock system that transform land, capital and labour into useful products that can be consumed or sold.

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

Farming system is as the way in which farm resources are allocated subject to the needs and priorities of the farmer in his local circumstances. The faming system is more risky than any other systems and specifically refers to a crop combination or enterprise mix in which the products and byproducts of one enterprise serves as input for the production of other enterprises.

Farming system is a resource management strategy to achieve economic and sustained production to meet diverse requirement to farm household while presenting resources base and maintaining a high level environmental quality.

Farming system is a complex inter related matrix of soil, plants, animals, implements, power, labour, capital and other inputs controlled in parts by farming families and influenced to varying degree by political, economic, institutional and socials forces that operate at many levels. Thus farming system is the result of a complex interaction among a number of interdependent components. To achieve it, the individual farmer allocates and manage four factors of production. Viz land, labour, capital and management.

Farming system consist of several enterprises like cropping system, dairying, piggery, poultry, fishery, bee, keeping etc. these enterprises are interrelated. The end product and wastes of one enterprise are used as inputs in others. The waste of dairying like dung, urine, refuse etc. is used for preparation of FYM, which is an input in cropping systems. The straw obtained from the crops is used as fodder for cattle's which are used for different field operations for growing crops. Thus different enterprises of farming systems are highly interrelated.

From all the above definitions a comprehensive definition can be made as- Farming system represents an appropriate combination of farm enterprises *viz.,* cropping system, horticulture, livestock, fishery, forestry, poultry and the means available to the farmer to raise them for profitability. It interacts with environment without dislocating the ecological and socio- economic balance on one hand and attempts to meet the food fibre, fodder and fuel needs as the national goal on the other. The farming system in its real sense will help in different ways to lift the economy of agriculture and standard of leaving of the farmers of the country as a whole.

Sustainability is the objective utilization of inputs without impairing the quality of environment with which it interacts. Therefore, it is clear that farming system is a process in which sustainability of production is the objective. The overall objective

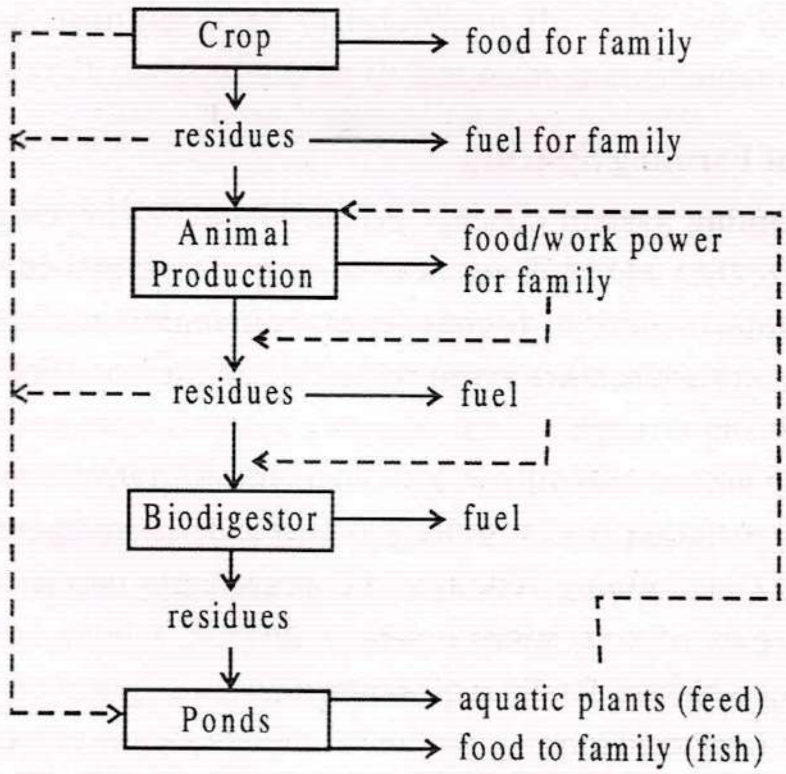

Fig. 1 : Concept of Farming System
(Interrelation of different compunets as a system)

is to evolve technically feasible and economically viable farming system models by integrating cropping with allied enterprises for irrigated, rained, hilly and coastal areas with a view to generate income and employment from the farm.

Objectives of Farming System :

1. To identify existing farming resources in specific areas and access their relative viability.
2. To formulate a productive system model involving main and allied enterprises for different farming situations.
3. To ensure optional utilization and conservation of available resources and effective recycling of farm residues within system
4. To maintain sustainable production system without damaging resources or environment.
5. To rise over all profitability of farmhouse hold by complementing main and allied enterprises with other.

Scope of Farming System :

Farming system concept primarily having importance to maximize the yield of all component enterprises to provide steady and stable income at higher level, rejuvenation of systems productivity and achieve agro-ecological equilibrium. Biotic stress management through natural cropping systems management and reducing the use of fertilizers and other harmful agro-chemicals to provide pollution free, healthy produce and environment to the society. Thus farming system as a concept takes into account of components of soil, water, crops, livestock, labour and other resources with farm family at the center managing agriculture related activity. Integrated farming system has the advantages of increasing economic yield per unit area per unit time, profitability, sustainability and provides balanced nutritious food for the farmers, pollution free environment and provide opportunity for effective recycling of one product as input to other component, money round the year and solve the energy, fodder, fuel and timber crisis, avoids degradation of forests and enhance the employment generation, increase input use efficiency and finally improve the livelihood of the farming community.

Principles of farming system :

1. Minimization of risk in agriculture
2. Recycling of wastes and residues
3. Integration of two or more enterprises
4. Optimum utilization of all resources
5. Maximum productivity and profitability
6. Ecological balance
7. Generation of employment potential
8. Increased input use efficiency
9. Use of end products from one enterprise as input in other enterprise

Advantages of farming system :

1. Productivity : Farming system provides an opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises. Time concept by crop intensification and space concept by building up of vertical dimension through crops and allied enterprises.

2. Profitability : The system as a whole provides an opportunity to make use of produce or waste material of one enterprise as an input in another enterprise at low cost. Thus by reducing the cost of production, the profitability and benefit cost ratio works out to be high.

3. Potentiality : Soil health, a key factor for sustainability is getting deteriorated and polluted due to faulty agricultural management practices *viz.,* excessive use of inorganic fertilizers, pesticides, herbicides, high intensity irrigation etc. In farming system, organic supplementation through effective use of manures and waste recycling is done, thus providing an opportunity to sustain potentiality of production base for much longer time.

4. Balanced food : In farming system, diversification of enterprises is involved and they produce different sources of nutrition namely proteins, carbohydrates, fats and minerals, etc. from the same unit land, which helps in solving the malnutrition problem prevalent among the marginal and sub-marginal farming households.

5. Environmental safety : The comprehensive nature of farming system is to make use or conserve the byproduct or waste product of one component as input in another component and use of bio-control measures for pest and disease control. These eco-friendly practices bring down the application of huge quantities of fertilizers, pesticides and herbicides, which pollute the soil water and environment to an alarming level. Whereas Integrated Farming System (IFS) will greatly reduces environmental pollution.

6. Income or cash flow round the year : Unlike conventional single enterprise crop activity where the income is expected only at the time of disposal of economic produce after several months depending upon the duration of the crop, the IFS enables cash flow round the year by way of sale of products from different enterprises *viz.*, eggs from poultry, milk from dairy, fish from fisheries, silkworm cocoons from sericulture, honey from apiculture etc. This not only enhances the purchasing power of the farmer but also provides an opportunity to invest in improved technologies for enhanced production.

7. Saving energy : Availability of fossil fuel has been declining at a rapid rate leading to a situation where in the whole world may suffer for want of fossil fuel by 2030 AD. In farming system, effective recycling of organic wastes to generate energy from biogas plant can mitigate to certain extent this energy crisis.

8. Meeting fodder crises : In IFS every inch of land area is effectively utilized. Alley cropping or growing fodder legume along the border or water sources, intensification of cropping including fodder legumes in cropping systems helps to produce the required fodder and greatly relieve the problem of non availability of fodder to livestock component of the farming system.

9. Solving timber and fuel crises : The current production level of 20 million m^3 of fuel wood and 11 million m^3 of timber wood is no match for the demand estimated of 360 m^3 of fuel and 644 million m^3 of timber wood in 2000 AD. Hence the current production needs to be stepped up through afforestation programmes with introduction of agro-forestry component in farming system without detrimental effect on crop yield. It will also reduce deforestation which will helps to preserving our natural ecosystem.

10. Employment generation : Various farm enterprises *viz.*, crop +livestock or any other allied enterprise in the farming system would increase labour requirement significantly and would help to solve the problem of under employment. An IFS provides enough scope to employ family labour round the year.

11. Scope for establishment of agro- industries : When the produce from different components in IFS is increased to a commercial level there will be surplus for value addition in the region leading to the establishment of agro-industries.

12. Enhancement in input use efficiency : An IFS provides good scope for resource utilization in different components leading to greater input use efficiency and benefit- cost ratio.

■

CHAPTER - 2

Classification of Farming Systems

The term farming system is a very broad concept which represents different agricultural and allied components and their activities. The term can be classified as follows-

A) Classification According to the Size of the Farm :

a) Collective farming.

b) Cultivation farming :

i) small scale farming

ii) large scale farming.

B) Classification According to the Proportion of Land, Labour and Capital Investment :

a) Intensive cultivation.

b) Extensive cultivation.

C) Classification According to the Value of Products or Income or on the basis of Comparative Advantages :

a) Specialized farming.

b) Diversified farming.

c) Mixed farming.

d) Ranching.

e) Dry farming.

D) Classification According to the Water Supply :

a) Rained farming.
b) Irrigated farming.

E) Classification According to Type of Rotation :

a) Lay system :
   i) unregulated lay farming
   ii) regulated lay system.
b) Perennial crop system.

F) Classification According to the Intensity of the Rotation :

a) Shifting cultivation.
b) Lay or fallow farming.
c) Permanent cultivation.
d) Multiple cropping.

G) Classification According to Degree of commercialization :

a) Commercialized farming.
b) Partly commercialized farming.
c) Subsistence farming.

H) Classification According to Degree of Nomadic :

a) Total nomadic.
b) Semi nomadic.
c) Partial nomadic.
d) Trans- humant.
e) Stationary animal husbandry.

I) Classification According to Cropping and Animal Activities :

J) Classification According to Implements Used for Cultivation :

a) Spade farming.
b) Hoe farming.
c) Mechanized or tractor farming.

The classification of farming system is illustrated as follows-

A) Classification According to size of farm :

a) Collective Farming : It includes the direct collection of plant products from non-arable lands. It may include either regular or irregular harvesting of uncultivated plants. Actual cultivation is not needed. The natural products like honey, gum, flower, silkworm cocoons etc. are collected. Such plant product may be collected from forest area.

b) Cultivation Farming : In this system, farming community cultivates the land for growing crops for obtaining maximum production per unit area.

(i) Small Scale Farming : In this type, the farming is done on small size of holding and other factors of production are small in quantity. The scale of production is also small.

Advantages :

i) Intensive cultivation is possible

ii) Labour problem do not affect the production.

iii) It is easy to manage the farm

iv) There is less loss due to natural calamities like frost, heavy rainfall, and diseases.

v) Per unit output increases.

Disadvantages :

i) small- scale farming cannot take advantages of various economic measures.

ii) Cost of production per unit is more.

iii) Mechanization of agriculture is not possible.

iv) Farmer does not get employment round the year.

(ii) Large scale farming : when farming is done on large size holding with large amount of capital, large labour force, large organization and large risk are called large- scale farming. In India

40 to 50 hectares land holding may be said large scale farming but in countries like America, Canada and Australia even 100 ha. Farms are also called as small farms.

Advantages :

i) Production of large scale farming is more economical. The cost of production per unit is less.

ii) per unit production is increased.

iii) Better marketing of agricultural products is possible. Processing, transportation, storage, and packaging of produce is economical.

iv) Costly machine like tractor, combined harvester can be maintained on the farm.

v) Subsidiary occupation such as dairy, poultry, bee keeping can be maintained on the farm.

vi) Proper utilization of factors of production is possible.

vii) Research work is possible.

Disadvantages :

i) If demand of produce decreases and production exceeds the market demand, there will be more loss to the large farm.

ii) In case of labour strike, all the farm operations may disturbed which causes be more loss on the farm.

iii) Due to natural calamities like frost, drought, flood, insects and diseases the large farm will suffer a lot.

iv) It will be difficult to manage large scale farm.

B) Classification According to the Proportion of Land, Labour and Capital Investment

The farmer on given plot of land obtains more or less definite quantity of yield of any particular time. If he wants to increases his output, he has two options- i) Bring more land under cultivation

ii) Apply more labour and capital to the same piece of land.

a) Intensive Cultivation : In intensive cultivation more labour and capital used in the same piece of land. In other words land remains fixed in quantity while other factors are increased. If the same land is rare due to population pressure, while labour and capital are comparatively cheap, intensive cultivation is preferred than extensive cultivation. The application of intensive cultivation method depends mainly upon- (i) Increasing population and (ii) Technical improvement. In the earlier stages of development population was small and technical knowledge of agriculture was also limited hence extensive method was adopted but, as population increases intensive cultivation become necessary and improvement in technique make its adoption is possible.

(b) Extensive Cultivation : When more area is brought under cultivation to increases the output it is termed as extensive cultivation. In extensive cultivation land is chiefly available but availability of other factors increases less proportionately. A cultivator wishing to increases his output may follow either intensive method or extensive method but the selection of these two methods is based on cost. If following extensive cultivation than by following intensive cultivation can raise the additional output more cheaply, extensive method of cultivation will be useful. If on the other hand intensive cultivation seems to be the cheaper method he will naturally adopt it. If land is cheaper and it can be had at a normal cost while labour and capital are comparatively costlier, extensive cultivation will be cheaper method of obtaining increased output. In early times when land was plentiful extensive cultivation was followed. The extensive and intensive cultivation go side by side in a country for a certain period of time and afterwards intensive cultivation may become more important method. In most of the countries extensive and intensive methods of cultivation generally go hand in hand.

C) Classification According to the Value of Products or Income or on the basis of Comparative Advantages :

a) Specialized Farming : The farm in which 50% or more income of total crop production is derived from a single crop is called specialized farming or The farm in which only single crop is cultivated for selling in the market and the income of the farm depends mainly on that crop is called specialized farming.

According to the definition, if 50% income is derived from paddy from any farm this is called paddy farm similarly sugarcane farm wheat farm, vegetable farm, orchard farm etc.

Advantages :

1. Better use of land : More profitable to grow crops on land best suited to it. e.g. jute growing or cultivation on swampy land in west Bengal.
2. Better marketing : It allows grading, processing, storing, transporting and financing the produce.
3. Less equipment and labour.
4. Costly and efficient machinery can be kept : A wheat harvester thresher can be maintained in a highly specialized wheat farm.
5. The efficiency and skill of the labor increased : Specialization allows a man to be more efficient and expert at doing a few things.
6. Farm records can be maintained easily.
7. Intensity of production leads to relatively large amount of output.
8. Better management : fewer enterprises on the farm are liable to be less neglected and sources of wastage can easily be detected.

Disadvantage :

1. There is greater risk when failure of crop or decreasing market price of the product.
2. It is not possible to maintain soil fertility-lack of crop rotation.
3. The productive resources i.e. land; labor and capital are not fully utilized.
4. Irregular income of the farm as they get income only once or twice in a year.
5. Proper Utilization of resources is not possible.
6. By-product of crop are not properly utilized, as numbers of livestock's are less in number.
7. Due to specialization of a single enterprise, farmers can not learn the knowledge about other enterprises.
8. Does not help in supplying all the food needs of the family members of the farmer.

b) Diversified Farming : A diversified farm is one that has several production enterprises or sources of income but no source of income equal as much as 50% of the total income from that source. On such farm farmers depends on several sources of incomes. It is also called as general farming.

Advantages :

1. Better use of land, labour and capital : Better utilization of area land through adoption of crop rotations, steady employment of farm and family labour and more profitable use of equipment are obtained in diversified farming.
2. The farmer and labour engaged all the year round in different activities.
3. Less risk to crop failure and market price of the product.
4. The byproducts of this farm can utilize properly as cattle, poultry, birds, etc. are reared with crop production.

5. Regular and quicker return is obtained from various enterprises.
6. Soil erosion can be checked as land kept under cultivated throughout the year
7. Soil fertility can be checked as land kept under cultivated throughout the year.
8. Diversified farming is less risky than specialized farming.
9. Best use of all equipment.

Disadvantages :

1. Do not fetch desirable profit so long as co-operative marketing facility is not there.
2. Proper inspection of different enterprises is difficult.
3. It is not possible to farmer to maintain all types of machinery required for different crops.
4. The wastage of farm in any farm is difficult to detect.

c) Mixed farming : Mixed farming is one in which crop production is combined with the rearing of livestock. The livestock enterprises are complementary to crop production; so as to provide a balance and productive system of farming. In mixed farming at least 10% of its gross income must be contributed by livestock activity. The upper limit being 45% under Indian condition. So the farm on which at least 10 to 49% income is found from livestock is called mixed farm. In mixed farming cow and buffaloes are included with crop production. If farmers are rearing cows, buffaloes, sheep goat, and fisheries with crop cultivation this type of farming is called diversified farming.

The scope of mixed farming to combination of crops and their complementary livestock enterprises of mixed farming would certainly include a vast majority of our farms, establishing a complementary relationship between crop and livestock enterprises.

Enterprises	Contribution to gross income of farm	Farming type
1. Cow and Buffalo only	10 to 49%	Mixed farming
2. Cow, buffalo and poultry	10 to 49%	Diversified farming

Advantages :

1. It offers highest return on farm business, as the byproducts of farm are properly utilized.
2. It provides work throughout year.
3. Efficient utilization of land, labour, equipment and other resources.
4. The crop byproducts such as straw, fodder etc. is used for feeding of livestock and in return they provide milk.
5. Manures available from livestock maintain soil fertility.
6. It helps in supplying all the food needs of the family members.
7. Intensive cultivation is possible.
8. If one source of income is lost he can maintain his family from other source of income.
9. Milk cattles provide draft animals for crop production and rural transport.
10. Mixed farming increases social status of the farmer.

In India the livestock is much closely connected with agriculture because animal power is the main source of power in agriculture. FYM is the main source for maintaining soil fertility and animals make good use of subsidiary and by-products on farms and in turn they provide milk under such circumstances mixed farming will most suit in Indian conditions.

Disadvantages :

1. Indigenous method of cultivation is used till now.
2. Draft and milch animals should be sold when they fail in production.
3. Healthy calf should be reared to replace age old animals.

d) Ranching : A ranch differs from other type of crop and livestock farming in that the livestock graze the natural vegetation. Ranch land is not utilized for tilling or raising crops. The ranches have no land of their own and make use of the public grazing land. A ranch occupies most of the time of one or more operators.Ranching is generally followed in Australia, America, Tibet and certain parts of India.

e) Dry Farming : Farmers in dry land area, where rainfall received is 750 mm or even less than that struggle for livelihood. The major farm management problem in these tracts, where crops, which are entirely dependent upon rainfall and the conservation of soil moisture is needed.

Dry Farming Involves the Adoption of the Following Practices :

a) Timely preparation of the land to a condition in which it is best able to receive and conserve the available moisture.

b) Timely and proper inter culturing during growth of the crop.

c) Improving the water holding capacity of the soil by the profitable application of organic manure.

d) Use of such implements as is capable or rapidly breaking of the surface of the soil.

e) Bunding of fields.

f) Use of optimum seed rates.

g) Thinning of excess plant populations.

h) Mixed cropping : Environmentally sustainable dry land farming systems gives emphasis on conservation and utilization of natural resources. Agronomic practices of conservation, tillage and mulch farming, rotational cropping, use of legumes and cover crops for improving soil fertility and suppressing weeds and efficient uses of cattle manure are some of the components of sustainable farming system.

D) Classification According to Water Supply

a) Rainfed farming.

b) Irrigated farming.

a) Rainfed Farming : Agriculture mainly depends on the rainfall in most part of the country. 80% of the total cultivated arable land is rainfed. Rainfed farming is very risky system of farming where the success of the crop depends on the cycle of the monsoon. Timely rainfall is the pre-requisite of this farming. The uneven rainfall is quite detrimental to crop production.

Characteristics of Rainfed Farming :

1. Crop and varieties, which can withstand moisture stress should be cultivated.
2. *Kharif* crops sown after receiving monsoon.
3. Not possible to adopt improved methods of cultivation. Only one or two crops are grown.
4. Crops rotation is not followed.
5. Soils of these areas are deficits in nutrient.
6. Mixed cropping should be practiced and adopt deep-rooted crops.
7. Short duration varieties fit well in rainfed areas.
8. The crops that are tolerant to drought should be cultivated.
9. Soil moisture should be preserve by mulching, FYM application, etc.

10. Soil erosion which may be called "Creeping death" of the soil is a worldwide problem, so necessary measures should adopt to keep the soil productive.

Principles of relevant components of environmentally sustainable farming systems should include.

1. Reduce soil erosion and improving soil conservations.
2. Inclusion of legumes and cover crops in crop rotations.
3. Agro-forestry as an alternate land use system and
4. Judicious use of organic waste.

b) Irrigated Farming : The crop can be grown throughout the year; moisture is not a limited factor.

Characteristics :

1. Round the year cropping becomes possible.
2. Intensive cropping is possible.
3. Production can be increased by proper utilization of productive resources.
4. Crop rotation can be executed properly due to adequate irrigation facility.
5. Manuring is safely done in irrigated crop.
6. The field experiment is possible, because of timely irrigation facility.

E) Classification According to Type of Rotation

There are different types of land use systems such as- arable farming, tree farming, grassland use etc. With considering to this, rotation means the sequence of this basic type of land use on a given field. Within arable farming there is also the term crop rotation which means the short- term sequences of different arable crops on one field.According to type of rotations farming systems can be classified as follows,

a) Lay System : In this system, several years of arable farming are followed by several years of grassed and legumes utilized for livestock production.

(i) Unregulated Lay Farming : In this system natural vegetation grasses, bushy growth on pasture is allowed to grow during the period of fallow. This is an improved managed pasture.

(ii) Regulated Lay System : During the period of fallow, certain types of grasses are grown or planted. These are the well managed pasture with fencing and adopting rotational grazing system.

b) Perennial Crop System : The crop which covers the land for many years e.g. Tea, Coffee, sugarcane. In some cases tree crops (oil palm, rubber) are alternated with fallow in other with arable farming, grazing etc.

F) Classification According to Intensity of the Rotation :

It is denoted by "R" which is simple and appropriate criteria for classification, and it gives the true relationship between crop cultivation and following within the total length of one cycle of utilization.

$$R = \frac{\text{No. of crops grown in a field}}{\text{Years of rotation}} \times 100$$

The length of the cycle is the sum of the number of years of arable in farming the number of fallow years. "R" indicates the production of the area under cultivation in relation to a total area available for arable farming.

a) Shifting cultivation : (R< 33%) In this case R is less than 33%. It means there is more number of years of fallow than actual cultivation.

b) Lay or fallow farming : (33% <R< 66%) In this case R is greater than 33% but less than 66%

c) Permanent cultivation : (R> 66%) In this large area is cultivated and small area is left fallow.

d) Multiple cropping : (R = or > 100%) If R= 150% means 50% area is under two crops in a year. If R = 300% means three crops in a year are being grown.

G) Classification According to Degree of Commercialization :

This classification of farming system is mainly depending upon the quantity of produce sold in the market for earning money as follows-

a) Commercialized Farming : More than 50% of the produce is for sale.

b) Partly Commercialized Farming : More than 50% of the value of produce is for home consumption.

c) Subsistence Farming : Virtually there is no sale of crop and animal products, but used for home consumption. Subsistence farming is a type of farming where the farmers of our country cultivate the crop in their land for the livings. Hence, the holding is small in size; so improved method of cultivation is not possible. They fail to meet the total requirement. They reared cattle, poultry, along with crop cultivation in limited land to meet their requirement.

Advantages :

1. Utilizing productive resources profitably.
2. Farmers with their family members engaged throught the year as they rearing cattle, poultry, etc.
3. Farmer meet their demand from the income from cattle, poultry, etc.
4. Byproducts used properly.

Disadvantages :

1. Fails to adopt improved crop cultivation technique due to small holding.

2. Cultivation mainly depends on monsoon rain.
3. Procurement of seed, fertilizer as and when required is difficult.
4. Income of this farm is very low.

H) Classification According to Degree of Nomadic :

This type of classification of farming system is useful where farming involves the rearing of animal for economic production and it is based on the basis of nomadic.

a) Total nomadic : In this system, the animal owners do not have permanent place of residence. They do not practice regular cultivation. Their families move with the herds.

b) Semi nomadic : Animal owners have a permanent place of residence, while Supplementary cultivation is practiced. However, for long periods of time, they travel their herd to distant grazing areas.

d) Partial nomadic : Farmer has permanent residence and who have herds at their disposal, which remains in the vicinity.

c) Transhumant : Means seasonal migration of livestock to suitable grazing ground or it is the situation in which farmer with a permanent residence sends their herd with herdsman for long period of time to distant grazing areas.

e) Stationary animal husbandry : Occurs where the animals remain on the holding or in the village throughout the entire year.

I) Classification According to Cropping Pattern and Animal Activities :

In this type farming system classified according to the leading crops and livestock activities of the holdings.e.g. Paddy holding, coffee banana holding. Rice-Jute holds, Sugarcane farming.

J) Classification According to Implements Used for Cultivation :

a) Spade farming : manual labour is used for different farm operations.

b) Hoe farming or Moe farming : Bullock power is used for cultivation.

c) Mechanized or tractor farming : Power operated big implements and machinery are used for cultivation.e.g. plough, tractor, combined harvester, etc.

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CHAPTER- 3

Components of Farming System

In the farming system, it is always emphasized to combine cropping with other enterprises or activities which are known as components of farming system. The productivity and economic efficiency of farming system is strongly depends upon the combination of such components. The various components of prevailing farming system in India can be enlisted as follows-

Wetland	Garden land	Dry land
Cropping	Cropping	Cropping
Fishery	Milch cows	Goat
Poultry	Buffalo	Agro forestry
Pigeon	Bio gas	Horticulture
Goat	Spawn production	Silviculture
Duck	Mushroom	Pigeon
Pig	Homestead garden	Rabbit
Mushroom	Emu	Farm pond Fish
Fodder	Silviculture	Quail
	Sericulture	Emu
	Farm pond Fish	Lac culture
	Nursery raising	Floriculture
	Goat	

1. Cropping :

It is most important component which is also considered as the back bone of farming system, because it can be implemented in all wetland, garden land and dry land types of farming system. There are many types of cropping systems and cropping patterns followed by farming to fulfill their food, fiber and fuel requirements. Cultivation of different cereal, pulses, oilseed, fiber, fodder and cash crops is the commonly implemented component by majority of farmers. It is also base for many other components as it provides raw material and inputs to these components.

2. Dairy farming :

Agriculture is the backbone of Indian economy and within agriculture livestock plays a vital role in providing sustainable income to farmers throughout the year. Due to failure of monsoon, crop production is becoming difficult and many farmers are shifting their activities to livestock and agroforestry. To make this economically viable, it is imperative to provide good managerial inputs (feed, fodder, housing, health care, breeding, general management and marketing) to exploit the genetic potential of livestock. Scientific management uses the limited resources of farmer to maximize returns from his farm. Efficient management of farm and effective marketing of products are the main responsibilities of the farmer and when properly carried out will make these operations productive and profitable.

Majority of the cattle owners in the country maintain only 1 or 2 milch animals as a integral part of the mixed farming system. They are utilizing family labour for various practices concerned with dairying. Sound management practices are of paramount importance for successful dairy farming, as they make the farmers efforts more efficient and productive. It is one of the economically viable enterprises that could able to provide constant income throughout the year to farmers. The success of dairy farming depends on the availability of inputs (feed and fodder) and better marketing facilities to milk. If these two essential items are made available then there could not be any problem for continuous generation of income. To get maximum profit from dairying, it is advisable to rear jersey cross bred cows since they come up very well in all climatic conditions, consume less feed and fodder, give more milk and possess comparatively better disease resistance. However, Holstein friesian crosses could be reared for higher milk yield in places of colder climate as they lack heat tolerance.

Different breeds of cow :

1. Milch breeds : Sahiwal, Sindhi, Gir, Deoni, Karan swiss, Phule Triveni.
2. Draft breeds : Amritmahal, Kangayam, Malvi, Siri, Hallikar, Khillari.
3. Duel purpose breeds : Hariana, Ongol, Tharparkar, Kankrej.
4. Exotic breeds : Jersey, Holstein friesian, Brown swiss.

3. Buffalo farming :

Buffalo breeds like Murrah crosses and even non-descript types could be reared for milk production. Buffalo can able to digest more of roughage than cows and thrive well on dry fodder. Majority of the dairy products in the country are based on buffalo. The higher fat percentage in buffalo milk is more profitable in dairy enterprises, particularly for toned and double toned milk. The higher fat content which generally ranges 7 -8 % and sometimes shooting up to even 12- 15 % enables the farmers to get a higher income as the price of the milk is based on fat content. Buffalo milk is comparatively cheaper to produce, since a buffalo is able to utilize coarse feed even rejected also.

Buffaloes are the major source of power in rice production.

They are used for ploughing and harrowing the paddy fields, for rice threshing and milling and transportation. They are slow, but heavy and strong and are well suited to work in muddy and submerged fields where they are able to pull heavier loads than cattle.

Breeds :

The important buffalo breeds are Murrah, Nili Ravi, Kundi, Bhadawari, Tarai, Nagpuri, Pandharpuri, Mandya, Kalahandi, Sambalour (Central region), Toda, Surti, Jaffarbadi and Mehsana, Dharwari.

4. Goat farming :

India, is blessed with the largest population of goats (about 23 % of the world population). The time has now come to employ goat rearing as an instrument in integrated farming system for profitable and assured dividends. The smallest viable unit of goats in 50 does and two bucks. One can establish organized goat farms in multiples 50 + 2, 100 + 4, 200 + 8 etc. Goats are small animals and easy to manage. Goats are also a source of bones, hooves, glands, offals, fibre, urine and droppings. Goats can find enough grazing throughout the year. Goats are browsing rather than grazing animals and take 80 % of their total intake as browse, which they obtain from a wide variety of vegetation. A flock of 95 she- goats and 5 bucks can be easily maintained as profitable unit. Goats produce a low fat meat. The dressing varies from 44- 49%. The average milk production is 1 litre/day/animal. Goat farming can be more profitable if good pastures are available.

Breeds :

1. Milch breeds : Beetal, Jamunapari, Malbari, Surti, Barbari, Jhakarna.

2. Meat breeds : Kashmiri, Osmanabadi, Sangamneri, Black Bengal, Marwari, Chegu, Sirohi, Zalawadi, Kutchi, Mehesana.
3. Fibre breeds : Angora, Gaddi, Pashmina, Chegu, Changthangi.

5. Sheep farming :

Sheep is also a small ruminant with a high adaptability to extreme climate. Sheep plays important role in the animal production in arid and semi-arid regions and largely in marginal and small holdings. Sheep rearing can be recommended as an occupation to the rural people especially to the weaker sections in hilly, drought prone and desert area. In the event of failure of seasonal rains, the rearing of sheep gives a helping hand to the farmers at the time of crisis arising from crop failure. When mixed farming is practiced, sheep forms in improving the economy of the farm. Sheep can thrive well in all agroclimatic conditions except in high rainfall areas. Sheep can subsist on low set and sparse vegetation whereas other species of farm livestock may be struggling to thrive. This is possible because of their inherent capacity to browse very close to the roots of herbage. Penning of sheep in harvested field enhances the fertility of the soil by the richness of nutrient in the faecal materials voided penning of sheep in the fields brings additional income to the flock owners. Some of the important breeds of sheep in India are- Deccani, Nellore, Bellari, Mandya, Banur, Nilgiri, Gurez, Bhakarwal, Gaddi, Lohi, Bikaneri, Marwari, Kutchi, Coimbatore white, etc.

6. Pig farming :

Pig farming is adapted to both diversified and intensive agriculture. Pigs convert inedible feeds, forages, certain grain byproducts into valuable nutritious meat. The faeces of pigs are useful in maintaining soil fertility. Pig raising fits very well with

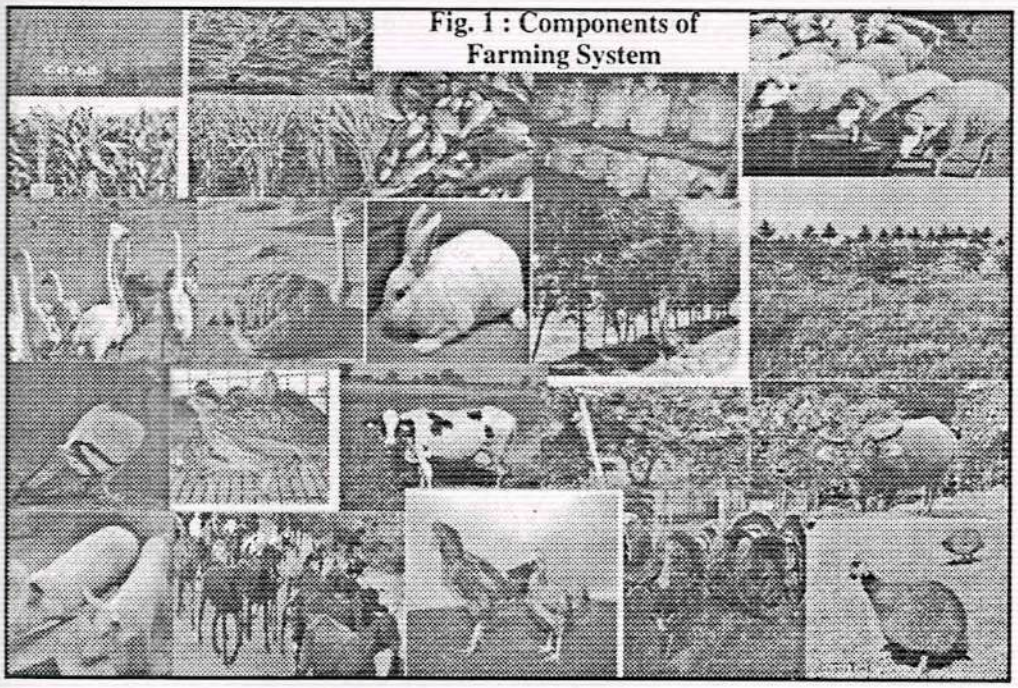

Fig. 1 : Components of Farming System

integrated farming system. Pig raising can be complimentary to intensive crop enterprise. The reproduction interval of pig is short and pigs give birth to many off springs at a time. Small sum invested in pig rearing can bring very good returns in a short time. Important breeds are- White Yorkshire, Barkshire, Poland china, Duroc Hampshire, Chester white.

7. Rabbit farming :

Integrated farming system is coming upto increase the per hectare yield, coupled with an increase in income and further generation employment. Rabbit rearing is one of the important activity of integrated farming system. Rabbit can also be reared in subtropical and plain regions. This enterprise does not require much investment. The income of the farm family can be increased easily through this enterprise due to its high proliferation rate coupled with very short gestation period and with minimal management practices. Rabbits have a high reproduction capacity and fast growth rate. Among the domestic livestock, rabbits are the most productive animals because of their small body size. They require lesser floor space than other livestock. Rabbits can be adapted to any set of circumstances, backyard rearing or commercial farming. Within a short span, they reach slaughter weight compared to cattle, sheep and goat. Rabbits are susceptible to heat stress as they do not have sweat glands. Rabbits have many advantages over other livestock. They eat forages and fibrous agricultural by products. They have a high feed conversion ratio and their meat is low in cholesterol.

It is possible to make broiler rabbits to attain 2 kg weight in 3 months. Unlike broiler chicken farming, rabbit raisers need not depend on hatcheries to get young ones as rabbits have a high reproduction capacity, low gestation period and fast growth. A female rabbit is capable of producing 50 young ones (kits) in a year.

Domesticable breeds of rabbit are- New zealad white, Gray giant, White giant, California, Soviet chinchilla, Satin and Rexes.

8. Camel farming

India possess about 10 % of the world camel population. In India, Rajasthan is having maximum camels followed by Haryana, Punjab, U.P. and Gujarat. Camels are valued as riding animals. A dromedary can carry 250 kg for 50 km/ day but when used for speed only they may cover even 150 km/ day. Camel hair of dromedary is shorter fiber of the insulating under coat. The annual hair yield from each camel is about 2.25 kg. Milk is another valuable product obtained from camel, a female may yield about 3-5 liters/ day. Meat and hides are other valuable products. The hide is used for making saddle. Average dromedaries weigh from 450 to 590 kg. Dressing per cent varies from 55 to 65%.

9. Poultry farming :

Poultry is one of the fastest growing food industries in the world. Poultry meat accounts for about 27% of total meat consumed worldwide. Poultry industry in India is relatively a new agricultural industry. Egg production may reach up to 95,000 million and broiler meat production 3.42 million metric tones by year 2013. The feed conservation efficiency of the bird is superior to other animals. Hence it is also a best component which can included in farming system.

10. Duck farming :

Ducks are the second largest source of table eggs in the country. There are about 23 million ducks in India. West Bengal has the highest duck population followed by Assam, Tamil Nadu, Andhra Pradesh, Bihar, Kerala, Orissa, Tripura, Jammu and Kashmir. Ducks predominantly are of indigenous type kept for egg production on natural foraging and have a production potential of about 130-140 eggs/bird/year. Improved strains of ducks are now available in the country and the farmers can start a side or main business.

Duck lays 40-50 eggs more than chicken. The duck egg is heavier than hen by 15-20 g. Ducks require lesser attention. Ducks supplement their feed by foraging on fallen grains in harvested paddy fields, insects, snails, earthworms, small fishes and other aquatic materials in lakes and ponds, hence incur reasonable feed cost. Ducks have a longer profitable life and lay well even in second year. Ducks do not require elaborate houses like chicken reducing on capital costs. Ducks are quite hardy, more easily brooded and more resistant to common avian diseases. Marshy river side, wetland and barren areas when chicken or any other type of stock do not flourish are excellent quarters for duck farming. Ducks do not have problem of cannibalism behavior. Ducks lay 95-98 % of their eggs early in the morning before 9 a.m. thus saving a lot of time and labour. Ducks are useful in controlling unwanted plants in ponds, lakes and streams like green algae, duckweed, pond weed, musk grass, arrow head, wild celery etc. (5-10 ducks/0.40 ha of water area). Ducks are good exterminators of potato beetles, grass hoppers, snails and slugs. Ducks can be used to free the bodies of water from mosquito pupae and larvae (6-10 ducks/ 0.40 ha of water surface). Ducks are suitable for integrated farming systems such as duck-cum-fish farming, duck farming with rice culture etc. In duck-cum-fish farming, the droppings of ducks serve as feed for the fishes and no other feed or manuring of the pond is necessary for fishes (200-300 ducks/ha of water area). Under integrated duck farming with rice culture, the ducks perform 4 essential functions *viz.*, inter tillage. weeding, insect control and manuring.

11. Guinea fowl farming :

Guinea fowl ranks third among the poultry birds. It is estimated that few million birds are raised every year. Reasonable net gains from guinea fowl production can be obtained when 2-3 crops of at least 500 heads are raised every year. Guinea fowls have been domesticated only in the recent past as a meat producing bird. Guinea fowls are hardy, gregarious in habit, move in flocks and thrive well in tropical as well as in temperate climates. They survive well even under the subsistence agriculture through scavenging and foraging. The three well known varieties of guinea fowls are the pearl, white and lavender.

12. Quails farming :

Quails are small birds that need very little floor space and feed. Hence, they require a modest investment. They mature very early and gives economic returns quickly. Quail eggs are small but rich in vitamins and minerals. Cholesterol conscious people can eat a few of these small eggs and regulate the intake of their food cholesterol. The eggs can also be pickled and stored for long periods. Quail meat is considered a delicacy. Quail husbandry is quite popular in Japan, Taiwan, China, Korea, Hong kong, France and Itally. It needs to be popularized in our country. The wild quails are migratory ground loving birds that hide themselves in bushes or in nests prepared in the hollow of the ground covered with leaves and grasses. Japanese quail is a domesticated species. The just hatched chicks weight about 7 g. Adult quails weigh 150-200 g. The female is heavier than the male. The male of Japanese quail is lighter than the female. Quails are prolific layers. Some females lay as early as 5 weeks of age depending upon the day length. The average age at first egg is being about 40 days. They are in full production by about 50 days of age. With proper care and management hens can lay 280-300 eggs / year. Eggs can be incubated successfully.

13. Turkey farming :

Turkey meat is among the most relished white meat apart from broilers and pork in the western countries. There is a highly integrated and thriving turkey industry in North America, Great Britain arid many other European countries. They are mainly reared as meat producers. Turkey farming is practically non-existent in our country. There are 7 breeds of turkey such as Bronze, white Holland, Bourban Red, Black, Slate, Narragansett and Beltsville small white. White breeds are preferred over coloured ones because coloured turkey contain a black pigment in their quill feathers. This pigment may spread under the skin if feathers are plucked improperly during the dressing give rise to blue backs. White turkeys lack these coloured pin feathers. Hence, they can be marketed at any age without any adverse effect on the appearance of the carcass. The marketable weight of turkey poults is around 4 kg. With proper environment, feeding regimes and health control measures this weight is achieved by about 12- 14 weeks of age.

14. Pigeon farming :

Pigeons when, properly kept, are very profitable as they find all their feed and raise 6- 10 pairs of young ones during the year. The best for table purposes pigeon varieties are the Homer, Dragoon, Lahore gola and the common clean legged Saraji. These breeds are large plump birds and can be easily kept. The largest birds should be selected for breeding purposes. Small birds as well as defective birds could be used for the table. Crossbred pigeons are large, hardy and very good for the table purpose.

15. Fish Farming :

The rural homestead ponds which are dotted all over the country are used for bathing, cleaning house hold utensils, washing and also for subsistence fish culture. But with the help of recent innovations it is possible to increase the fish productivity of such ponds through proper management. The ponds can be used for fish seed production if they are of seasonal nature or for table size fish production if they retain water for long duration or throughout the year. Appropriate technology of fish culture involves eradication of unwanted fish species by using some fish poison such as bleaching powder or mahua oil cake, weed, clearance, manuring and fertilization, stocking and daily feeding. Besides these activities, in small household ponds women can also undertake such allied activities as breeding of carps and net making for fishing in ponds. The agricultural labour force mostly has employment for about 180-225 days/ year. The remaining time could be utilized for aquaculture activities (net making, seed rearing, culture of fish fry, fingerlings, table fish, prawn culture, crab culture and frog rearing).

16. Prawn farming :

Traditionally, prawn farming developed from incidental by-catches from fish ponds or flooded fields in India and south East Asia. The product was mainly sold locally and it was only with the advent of refrigeration and improved transportation that access to the higher priced city and international markets is possible. This so increased the value of the by-catch that many farmers encouraged the impoundment of naturally occurring post-larval prawns in their ponds or rice fields and ultimately set side ponds specifically for prawn culture. Today, traditionally based farms predominate in countries like Indonesia, India, Bangladesh, Philippines and Thailand. Most prawn farms depend heavily upon naturally occurring juvenile or seed prawns entering the ponds with the tide. Professional catachers supplement supply by trapping or netting the post-larvae as they migrate inshore and into the lagoon or mangrove nursery areas. Increasingly heavy demand throughout many of these regions, the inevitable uncertainties associated with reliance upon a natural resource together with pollution and destruction of the mangrove nursery areas for farm ponds and other enterprises have led to increasing demand for hatchery raised juveniles. Two groups of tropical prawn or shrimp can be raised by culturist. The marine Penaeid prawns provide the bulk of farmed crustaceans, while a species of Caridean prawn (Macrobrachium rosenbargii) which inhabits fresh water but returns to brackish water to bread, supports a wide spread but much smaller industry.

17. Sericulture :

Sericulture is a part of agriculture as it includes cultivation of mulberry. Similarly it is also an art from purchasing of eggs up to spinning of silk and also industrial part, which includes cocoon killed out for fabrics. Mulberry forms the basic food material for silk worms. Silkworm rearing is an art in the hands of rural people. Reeling of the silk from the cocoons formed by the worms is an industry of different financial investment. Production of mulberry leaves on scientific lines is essential for organizing sericulture on sound economic lines. Sericulture means practice of rearing silkworms with mulberry cultivation for production of silk on commercial basis. The total area under mulberry is 240 thousand ha in the country. It plays an important role in socio- economic development of rural poor in some areas. Climatic condition is favorable for mulberry cultivation and rearing of silk worms throughout the year in India. Government has implemented specific policies for the development of this component of farming system as an industry.

18. Lac farming :

The lac producing insect *(Laccifer lacca)* is a scale insect. It is cultivated mainly in India, Thailand and Burma which produce over 90% of the world supply of lac (shellac). India produces the maximum amount of lac (about 90%) from Bihar, Orissa, Madhya Pradesh, West Bengal, Assam and Utter Pradesh. Small quantities of lac are produced in Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra and Punjab. Lac is a resinous secretion of this insect. The insect feeds on certain tropical trees and is injurious to its hosts. In India, there are two strains of the lac insect. The strain that thrives on Kusum tree is called Kusum strain. The one that comes up on all other hosts is known as Rangeeni strain. Both the strain has two generations a year. About 90% of lac produced in India comes from rangeeni strain.

19. Apiculture :

' Bee keeping can be adopted as a part time or full time occupation. It provides opportunities for small, medium and large scale farming systems. It also provides gain full employment close to home. It requires little investment and infrastructure. It provides highly nutritious honey and cash income. Hive products are harvested locally and do not require special storage facilities. It earns foreign exchange. It enhances the productivity and quality of agriculture, horticulture and fodder crops. It conserves the diversity of plant kingdom. The Indian bee *(A. cerana)* colonies nest in the concealed dark places. Such colonies can be searched in the wild habitats and captured. The colonies can also be purchased by the bee keeping cooperative societies and other beekeepers. The apiary has to be established in the area where rich source of bee flora is available throughout the year. The area should be cool and calm.

Migrating bee colonies to the areas where rich source of bee flora is available is highly beneficial in terms of build out of colonies and honey yield. After the second year, the percentage of profit will be 99, 91 and 91% respectively over the initial non-recurring investment.

20. Mushroom cultivation :

Mushroom is the fungal fruiting body technically called sporophore which produces large number of spores which are the seeds of this plant. Mushroom lacks chlorophyll and hence can not produce its own food and depends on other living or dead plants for its food. More than 10,000 species of edible mushrooms are used as food in the world and about 70 species are suited for artificial cultivation. Mushroom cultivation is done indoor and hence very little land area is required.

Recycling of agro-wastes generates and supplements the income in the farming system. Mushroom produces high quality and quantity of protein from worthless agro-wastes. The protein of mushroom is superior to those of plant and is rich in lysine. Paddy straw mushroom *(Volvariella volvacea)* is being grown in some parts of the country catering the demand of local consumers only. Many growers (in central and southern India) are showing interest in the oyster mushroom *(Pleurotus sp.)*. Oyster, shitake and black ear mushrooms fetch better price than white button mushroom in the world market. India with its varied agroclimatic conditions, availability of agro wastes in abundance and manpower is most ideal to produce all the major mushroom varieties being produced in temperate, subtropical and tropical regions.

Mushrooms are well known for their delicacy and flavour. At present world mushroom production is estimated to be about 4 million tones per annum whereas in India, it is hardly about 15000 tones per annum. The oyster mushrooms and milky mushrooms can be grown in plains almost throughout the year. But, the white button mushrooms can be grown only in temperate climate preferably in hills. Paddy straw mushroom can be grown only during summer months (April- July).

Only a few are commercially cultivated *viz.*, white button mushroom *(Agaricus bisporus)*, oyster mushroom *(Pleurotus ostreatus and Pleurotus sajor-caju)*, paddy straw mushroom *(Volvariella volvacea)*, Japanese mushroom *(Lentinusedodes)*, winter mushroom *(Flammulina velutipes)* and black ear mushroom *(Auricularia polyticha)*. Among the cultivated types, button and oyster mushrooms can be grown in the most part of India.

21. Flower cultivation :

In farming system, small area is allocated for flower cultivation to meet the aesthetic requirement of the farm family. Flower cultivation can be also included in farming system where the farm is located very nearer to city market. The important flower crops are rose, marigold, gerbera, aster, chrysanthemum, gladiolus, tuberose etc. It is the most suitable component of farming system for intensive cultivation to gain more income from a small farm unit.

22. Nursery keeping :

The method in which plantations are raised by direct sowing consumes a large quantity of seeds. Raising the tree plantations includes planting in grazing lands and wastelands. Environmental factors of these sites are often harsh. At such sites, plantations by direct seed sowing are unlikely to succeed. Hence, it is of primary importance that appropriate quantity of seedlings should be raised in the nurseries for good plantations. The growth of seedlings at the initial stages after planting largely depends on the seedling quality. Hence, the nursery technology of raising a good quality seedling is very important. Seedlings are raised for the use of the department as well as for the use of the other farmers in the region.

It is prepared and maintained by farmers and their families on their own land.

Young seedlings require special attention during the first few weeks after germination. It is easier and economical to look after the young seedlings growing in nursery bed in a small area. Majority of fruit crops is propagated by vegetative means, which require special skill and after care before transferring them in the main field. In nursery, all these can be provided successfully. Cuttings are best rooted in mist chamber, which is an integrated part of a nursery. Direct sowing method is not so successful when compared with transplanting of seedlings raised in nursery. Nursery hardened plants are preferred for causality replacement in orchard.

23. Horticulture :

The demand and production curve of different horticultural crops including with fruit, flower and vegetable crops is observed to increasing day to day. For the fulfillment of market demand and receiving higher economic return, a large amount of farmers included cultivation of horticultural crops as a component of farming system in garden land and dry land area. The food processing industry also developing on the support of this component with its parallel economy and creation of employment for people.

24. Agroforestry :

Cultivation of forest trees combining with cultivation of agronomical crops to fulfill the food, fodder, fiber and fuel needs of farmer is known as agroforestry. It is the best component for dry land farming system to uprising the economical and social condition of farmers with maintaining the sustainability.

In India Agroforestry system has following sub components-

a) Agro-silviculture= crops+ trees

b) Silvi-pasture= trees+ fodder crops+ animal

c) Agri-silvi-pasture= crops+ trees+ fodder+ animal

d) Horti-pasture= fruits+ fodder +animal
e) Agri-horti-silvi= crops+fruit crops+ trees
f) Agri- horti- silvi- pasture= crops+ fruit crops+ trees+ fodder+ animal

25. Vermicomposting :

Earth worms occur more than 80 per cent of soil invertebrate biomass and 10-15% net primary production. It acts as an aerator, crusher, mixer, grinder, chemical degrader and biological stimulator in soil. Earthworms known to help the soil respiration, nutrition, excretion, stabilization etc. It causes tunneling, buffering action, regulates soil temperature and thus stimulate useful activity of aerobic microorganisms. The earthworms feed on partially decomposed organic matter and their digestive tract converting the waste products into worm cast, which is passed out of their bodies in the form of granular aggregates. The earth worm feed 4-5 times of their body weight daily. One kg of earth worm could decompose approximately 4.5kg of organic waste in 24 hours. Vermicompostings contain more excreta, earthworm cocoons and undigested feed which forms as an excellent organic manure. The earthworm castings would improve the humus content of soil which has direct implications on long term soil fertility and sustainability. Earth worm causes increase in humus content would automatically influence higher uptake of major and micro-nutrients in plants.

There are more than 300 species of earthworms in the world and about 50 species in India. *Eudrilus eugeniae, Elsenia fetida* and *Perionyx excaratus* are some of the species of earth worms which are found to be beneficial as they produces around 400 kg of compost/ha/ year.

26. Biogas Plant :

Biogas is a clean, unpolluted and cheap source of energy, which can be obtained by a simple mechanism and little investment. The gas is generated from the cow dung during anaerobic decomposition. It can be used for cooking purpose, fuel for lamps, etc. Slurry is obtained after the production of biogas which is enriched manure and more efficient organic manure than regular cow dung or compost. Dry slurry contains about 1.8 %- N, 1.10 %- P_2O_5 and 1.50% - K_2O.

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CHAPTER - 4

Integrated farming Systems

Specialized Farming :

Specialization involves the intensification of the agricultural activity aimed at maximization of the production/ unit area/ unit time. This involves improvement of operational efficiency and speed of operation at each step. The specialized farming system is thus focused on single cropping system or sequence of farming enterprise like animal breeding, dairying so as to achieve the "Highest degree of Precision Management" with minimal diversion of resources to diverse crop or enterprises, differing widely in managerial skills and involving extremely different implements and handling capabilities for the produce.

The availability of Improved seeds and breeds and supply of high inputs like chemical fertilizers, irrigation and pesticides have led to perceptible increase in crop production, specially of wheat and rice in India during the 1970's and 1980's However in India both the major food crops have failed to maintain the uptrend of production. This fact shows that the application of wrong technology or over-exploitation of natural resources may have short term gains but could often lead to ecological degradation, no longer sustainable by man. In addition, adoption of such technology has created serious problems of salinity, water logging, soil erosion and degradation of environment including air and water pollution. Hence, to meet the need of adopting the suitable farming system techniques for sustainable food production, the emphasis was given on the development of farming systems which are most suitable and efficient in the available resources and climate of the particular area.

Integrated Farming System :

It can be defined as, the location specific integration of various agricultural enterprises viz, cropping, animal husbandry, fishery, forestry, mushroom, sericulture, poultry, piggery etc. suited for the given agro- climatic condition with optimal recycling and utilization of resources for maximum family income and employment generation with sustainability .

Integrated farming System (IFS) introduces a change in the farming techniques for maximum production in the cropping pattern and takes care of optimal utilization of resources. The farm wastes are better recycled for productive purposes in the integrated farming system. Unlike the specialized farming system (SFS), Integrated farming systems activity is focused round a few selected, interdependent interrelated and often inter- linking production systems based on a few crops, animals, and related subsidiary productions.

Advantages of Integrated Farming System :

1. Higher food production to equate the demand of the exploding population of our nation
2. Increased farm income through proper residue recycling and allied components
3. Sustainable soil fertility and productivity through organic waste recycling
4. Integration of allied activities will result in the availability

of nutritious food enriched with protein, carbohydrate, fat, minerals and vitamins

5. Integrated farming will help in environmental protection through effective recycling of waste from animal activities like piggery, poultry and pigeon rearing
6. Reduced production cost of components through input recycling from the byproducts of allied enterprises
7. Regular stable income through the products like egg, milk, mushroom, vegetables, honey and silkworm cocoons from the linked activities in integrated farming
8. Inclusion of biogas & agro forestry in integrated farming system will solve the prognosticated energy crisis
9. Cultivation of fodder crops as intercropping and as border cropping will result in the availability of adequate nutritious fodder for animal components like milch cow, goat / sheep, pig and rabbit
10. Firewood and construction wood requirements could be met from the agroforestry system without affecting the natural forest
11. Avoidance of soil loss through erosion by agro-forestry and proper cultivation of each part of land by integrated farming
12. Generation of regular employment for the family members of small and marginal farmers.

Components of integrated farming system :

1. Crops, livestock, birds and trees are the major components of any IFS.
2. Crop may have subsystem like monocrop, mixed/intercrop, multi-tier crops of cereals, legumes (pulses), oilseeds, forage etc.

3. Livestock components may be milch cow, goat, sheep, poultry and bees.
4. Tree components may include timber, fuel, fodder and fruit trees.

Goals of Integrated Farming System :

1. Maximization of yield of all component enterprises to provide steady and stable income at higher levels.
2. Rejuvenation of system's productivity and achieve agro-ecological equilibrium.
3. Control the build-up of insect- pests, diseases and weed population through natural cropping system management and keep them at low level of intensity.
4. Reducing the use of chemical fertilizers and other harmful agro-chemicals and pesticides to provide pollution free, healthy produce and environment to the society.

■

CHAPTER - 5

Integrated Farming System for Irrigated Upland

India is predominantly an agricultural country. More than 75 percent of the people depend directly on agriculture. Majority of the farming community are small and marginal farmers. Due to many obvious constraints small and marginal farmers find difficult to sustain their living standards and one reason is low returns from traditional cropping methods. To increase the economic status of agriculture, the solution would be integrating agriculture with other enterprises based physical, biological and socioeconomic resources.

Upland areas play a very important role as watersheds in the conservation of water resources and the maintenance at a stable ecosystem. Proper management of upland areas is therefore a key issue in the successful utilization of land resources. The most common problems encountered in upland farming are erosion, water shortage, low soil fertility and productivity. An integrated farming systems approach has been developed for the sustained improvement of productivity. This is based not on the upland production of food crops which tends to be a high input, high risk activity but an integrated farming system based on perennial crops and livestock in which food production is limited to that needed for local consumption.

A combination when carefully selected and planned by keeping in view the soil and environmental conditions will pay greater dividends. They also envisaged that to mitigate the risks and uncertainties of income from conventional cropping and to reduce the time lag between investment and returns, it is essential to use integrated farming system approach in production programme that yields regular and evenly distributed income throughout the year and is not subjected adversely to vagaries of nature. The biggest edge such farming systems have on other types of farming system is the abundance of water available for crop growth. This makes it possible for the cultivators to expect a decent harvest, thus earning a reasonable income from cropping enterprise. But if other enterprises were taken along with crop husbandry in properly selected combinations, it would increase the productivity of the farm many folds and thus would virtually change the economic scenario of the place.

Characters of irrigated upland :

1. Farming will be for around 9-12 months
2. The sources of water are wells and deep bore wells in addition to rainfall
3. The climate is arid to humid
4. Water management is the main criteria, i.e. economic use of water
5. Fertilizer use- liberal to maximize the yield.

Constraints :

1. Salt affected soils are more
2. Energy for lift irrigation is a must, but availability is a problem

Components suitable for irrigated upland farming systems :

The most suitable components are dairy, goat rearing, poultry, biogas, spawn production, mushroom, vermicompost, homestead garden, apiary, silviculture and sericulture. The appropriate integrated farming system in upland areas should be consist of a package of technology which generally contains five components such as soil and water conservation and management, cropping systems (food and fodder crops), livestock, tree crops and an economic evaluation. However, food crop production in upland areas is a high risk activity which needs a high level of inputs to overcome the physical constraints including a lot of labour. Even so, production is low and unstable because of the biotic constraints (pests and diseases) and climatic factors. It is nearly impossible for subsistence farmers to overcome these constraints without assistance and subsides from the government. The solution seems to be an integrated farming system for upland areas in which perennial crops are the main component while the food crop component is only enough to satisfy the needs of the farm family or village community. Organic matter plays a very important role in sustaining soil productivity. Hence, the crop residues, animal wastes, cut biomass of hedgerow crops and cover crops should be managed properly to increase soil productivity. This type of integrated farming system based on the maximum utilization of land resources, solar radiation and includes following components.

1. Soil fertility management :

Of the major nutrient problems encountered in upland farming, phosphorus deficiency is the main constraint followed by potassium deficiency. Fertilizer use efficiency is low due to the high rates of phosphorus fixation and the rapid leaching of nitrogen and potassium. The application of organic matter in the form of composted manure and crop residues increases the efficiency of applied chemical fertilizers. Soil acidity is a major constraint in most upland soils because of aluminum toxicity. Lime can be used to overcome this constraint while tolerance to aluminum saturation varies depending on the kind of crop. Upland crops rotation systems should consider lime applications for the most acid sensitive crops. One of the major problems in cultivating acid upland soils is the reduction in productivity as a result of the decline in soil organic matter. This decline is more rapid if all the crop residues are removed or burned as is often practiced by farmers. Soil is a living system which converts all fertilizers applied into available as well as non-available forms for plants. The key factor in this process is soil organic matter which act as biological buffer to maintain a balanced supply of available nutrients for the plant roots. Not only the direct application of organic matter but the cultivation of fast growing legume trees as hedge row or as an alley crops are effective in increasing soil organic matter.

2. Soil conservation and erosion control :

Acid upland soils are highly susceptible to erosion. The loss of top soil from erosion and runoff as well as soil compaction from mechanized land clearance are the main causes of declining soil productivity in acid upland soils. The most appropriate methods of controlling erosion are mulching with cut branches of legume trees such as- Flemengia congesta grown in a hedge row or as an alley crop in combination with minimum tillage on flat and sloping land. Soil conservation practices such as mulching with legums, terraces with grass edges and alley cropping at row cropping of legumes must have first priority in any upland farming system.

3. Cropping system :

The basic idea of a cropping system based on soil conservation is that the canopy should cover the soil surface as much as possible to reduce the force of falling rain drops, the rate of runoff and soil loss. It should also be able to produce high yields. Among the cropping systems a combination of cereals and legumes (e.g. maize + soybean - maize + peanut – cowpea / green gram) proved to be the best. This type of system gave good yields in terms of calories, protein, cash income and crop residues which could be used as mulch or fodder.

a) Tree crops : Tree crops are planted in rows running east west. Different types of tree are planted in sequence avoid shading and to maximize the utilization of solar radiation.

I stage : Coconut, Oil palm

II stage : Clove, cinnamon, jack fruit

III stags: Banana, orange, pineapple, root crops, medical herbs, spices

b) Food and forage crops : Food and forage crops are planted during IV stage. By this time, some of the soil physical constraints have in alleviated while there is good erosion control. The management of food crops includes proper crop rotation and the utilization of crop residues.

4. Livestock :

This component is very important in integrated farming system. Raising livestock helps to maintain soil productivity by recycling organic matter while the grass planted on the edges of terraces for fodder helps to control erosion. Livestock also represent capital investment and an additional source of income as well as draft power for the farmer.

5. Fisheries

Fisheries are included if the soil and topography make it possible to construct a pond to catch runoff in the rainy season. This pond also serves as a water source for irrigation, fish rearing and other purposes.

6. Biogas plant :

Based on the number of dairy animals available, a biogas plant can be constructed near the farm stead itself. The dung collection from 4-5 milch animals is enough to generate 2 m^2 capacity of biogas plant.

7. Spawn and Mushroom Production :

From the cropping component, sorghum grain can be obtained for spawn production. From this mother spawn, inoculate the sorghum seeds to produce spawn bottles by recycling the biogas plant. Mushroom cultivation is done in thatched shed with less expenditure. *Pleurotus sp.* commonly grown edible mushroom which can be grown easily. Paddy straw is cheap and a good substrate for cultivation of Oyster mushroom.

8. Silkworm rearing :

The silkworm rearing can be completed in about 25- 30 days. For this, mulberry is to be cultivated in 0.2 ha. Silkworms can be reared 5 - 6 times in a year. It gives more employment generation also.

All types of soil with well drained capacity are suitable. Soils of pH- 6.5 are preferable. Kanwar- 2, MK- 2, S- 41, S- 36, S- 54, MH- 1 and MH- 2 are the varieties suitable for cultivation. Mulberry leaves of 25-30 t/ha can be harvested per annum.

9. Apiary :

Few boxes for honey bee rearing can be kept in suitable places. Farmers can get additional income by keeping l- 2 honey bee boxes nearer to their home in the garden.

Experiment results on farming systems for irrigated upland revealed that integration of cropping with components like dairy, biogas and mushroom or fish resulted in higher productivity than cropping alone. Integration of 0.32 ha each of sorghum + red gram-sunflowers coriander, maize + fodder cowpea — cotton + coriander and perennial fodder grass + legume fodder (lucerne) with dairy (6 cows + 4 calves), biogas (2 m^3 capacity) and mushroom (2 kg/ day)

+ spawn production (10 bottles/ day) recorded higher productivity than the cropping alone with sorghum- cotton (0.50 ha) and maize-cotton (0.50 ha) cropping systems. Cropping + dairy + biogas+ fish + mushroom integration recorded the highest net return. Integration of cropping with dairy + biogas + mushroom generated the highest employment of 875 man days. The allied enterprises generated additional employment of 469 man days providing opportunity for 1.28 family members to be employed round the year.

The field studies on the development of appropriate integrated farming system modules for the small farmers of irrigated upland was initiated in TNAU, Coimbatore during 2010. The various components integrated were Crop- Horticulture- Dairy- Goat rearing- Biogas plant- Vermicompost unit. After assessing the need of the dairy and goat components in terms of green fodder, dry fodder and concentrated feed requirements the existing promising systems were slightly modified. In the cropping component, five cropping systems *viz.*, Maize - cowpea (grain)- tomato/ radish (0.20 ha), Bhendi- maize + cowpea (fodder)- sunflower (0.20 ha), Chillies-maize- green manure (0.20 ha), Cowpea (veg.)- cotton- sunflower (0.25 ha) and Cumbu Napier grass and Desmanthus (0.17 ha) were included in a total area of 1.02 ha. To supplement the fodder requirement further, particularly during the lean summer months. *Sesbania grandiflora* (Agathi) was raised along the boundary of the cropping unit. To effectively utilize the border and boundaries of the cropping area, plants like annual moringa (25 nos.) and curry leaf (50 nos.) were planted. An area of 0.16 ha was allotted for the horticultural component (Banana, Aonla, Guava and Sapota). The livestock unit consists of dairy and goat. Two numbers of crossbred Holstein Friesian cows with calves forms the dairy. In the goat unit 10 females and one male (Buck) of Tellicherry breed are being reared. 2 m^3 biogas unit was constructed for recycling of cow dung. To recycle the animal waste and crop residue vermicompost unit was constructed.

Table- 4.1 Economics of integrated farming system :

No.	Component	Size	Total cost (Rs.)	Gross return (Rs.)	Net return (Rs.)	Contribution (Rs.)
1.	Crop	1.02 ha	94600	194575	99975	48
2.	Horticulture	0.14 ha	12461	12545	85	—
3.	Dairy	2 cows+ calves	68441	134077	65636	32
4.	Goat	10+1	37352	72121	34769	17
5.	Biogas plant	2 m^3	—	720	4549	2
6.	Vermicompost	50 m^2	11706	13956	2250	1
		Total	224558	427992	207263	100

Siddeswaran (2012)

The overall performance of the individual components in terms of cost and returns for a farm unit of 1.20 ha are summarized in Table- 4.1. Cropping component recorded the net return of Rs. 99,975. Dairy and goat unit registered net retain of Rs. 65,636 and Rs. 34,769 respectively. In the biogas unit daily 2 m^3 biogas was produced with the value of Rs. 4,549. From the vermicompost unit production of 12 tonnes was obtained and recycled in the crop component. A net return of Rs. 2,07,263/ year was realize from 1.20 ha farm unit with crop- horticulture- dairy-goat rearing- biogas plant- vermicompost as a component.

Table 4.2

Proposed farming system model for different farmer categories

Type of farmers Components	**Marginal farmers (<1.0 ha)**	**Small farmers (1.0-2.0 ha)**	**Medium and big farmers (>2.0 ha)**
Cropping area (ha)	0.40	1.00	5.00
Dairy unit (milch animals + calves)	3 +2	3 +2	15 +10
Biogas plat capacity (m^3)	01	01	02
Spawn production (bottles/ day)	—	6	15
Mushroom production (kg.)	—	3	10
Apiary unit (no.)	1	2	10

Table-4.3.a

IFS model suggested for upland irrigated area in Maharashtra for 1.00 ha area

Sr. no.	Component	Area (ha)
1.	Cropping : Soybean-Wheat- vegetables	0.30
2.	Cropping : Maize -Onion - green gram	0.20
3.	Cropping : Perarlmillet- Chickpea - Cowpea	0.10
4.	Fodder : Lucerne (perennial)	0.10
5.	Fodder : Hybrid Napier grass (perennial)	0.02
6.	Horticulture : Mango orchad	0.20
7.	Dairy animal & poultry shed, Vermicomposting & compost pit	0.08

Table - 4.3.b

Economics of IFS model given in table - 4.3a

Component	Gross return	Cost of production	Net return	B : C Ratio
Crop	98855	47853	51002	2.06
Animal	117717	51427	66290	2.29
Poultry	55190	31365	23825	1.76
Mango + onion	32000	6000	26000	5.33
Total	303762	136645	167117	2.22

Table- 4.4

Productivity, economics, residue addition and employment generation of different farming system in upland irrigated area on 1 ha land

Sr. no.	Farming system	System productivity	Net return (Rs./ha) (kg/ha)	Employment generation (man days)	Residue addition (kg/ha)
1.	CCS	11091	35021	394	2250
2.	IFS-1	33923	117850	692	5800
3.	IFS-2	34891	126839	704	6046
4.	IFS-3	45980	168530	875	7989
5.	IFS-4	12068	40722	414	7446
6.	IFS-5	34495	125267	705	9337
7.	IFS-6	33271	115958	695	9527

(Sivamurugan, 2001)

Where,

CCS : Conventional cropping system

IFS-1 : crop+ dairy

IFS-2 : crop+ dairy+ biogas

IFS-3 : crop+ dairy+ biogas+ mushroom

IFS-4 : crop+ fish

IFS-5 : crop+ fish+ dairy+ biogas

IFS-6 : crop+ fish+ dairy

CHAPTER - 6

Integrated Farming Systems for Rainfed and Arid Region

A) Integrated farming systems for Rainfed Region :

Out of the 143 million ha of total cultivated area in India, 101 million ha (i.e. nearly 70 percent) area are rainfed. Hence, Indian agriculture is predominantly a rainfed agriculture under which both dry farming and dryland agriculture are included. In dryland areas, variation in amount and distribution of rainfall influence the crop production as well as socio-economic conditions of farmers. The dryland areas of the country contribute about 42 percent of the total food grain production. Most of the coarse grains like sorghum, pearlmillet, fingermillet and other millets are grown in drylands only. Dryland agriculture in India is always a challenge, since crop production in dryland areas depends on monsoon showers.

The major problems of dryland farmers are -

1. Unpredictability of onset, duration and distribution of rainfall
2. Unfavorable crop growth environment
3. Limited choice of crop varieties
4. Low fertility of soils
5. Short growing seasons.

There is an urgent need to formulate strategies to improve agriculture production in the dry farming tracts.

Technology to improve dryland agriculture :

1. Crop Substitution :

Traditional crops/varieties which is efficient utilizer of soil moisture, less responsive to production input and potentially low producers should be substituted by more efficient ones.

2. Cropping Systems :

Increasing the cropping intensities by using the practice of intercropping and multiple cropping is the way of more efficient utilization of resources. The cropping intensity would depend on the length of growing season, which in turn depends on rainfall pattern and the soil moisture storage capacity of the soil.

3. Fertilizer use :

The availability of nutrients is limited in drylands due to the limiting soil moisture. Therefore, application of the fertilizers should be done in furrows below the seed. The use of fertilizers is not only helpful in providing nutrients to crop but also helpful in efficient use of soil moisture. A proper mixture of organic and inorganic fertilizers improves moisture holding capacity of soil and increase drought tolerance.

4. Rain water management :

Efficient rainwater management can increase agricultural production from dryland areas. Application of compost and farm yard manure and raising legumes add the organic matter to the soil and increase the water holding capacity. The water, which is not retained by the soil, flows out as surface runoff. This excess runoff water can be harvested in storing dugout ponds and recycled to donor areas in the server stress during rainy season or for raising crops during winter.

5. Watershed management :

Watershed management is an approach to optimize the use of land, water and vegetation in an area and thus, to provide solution drought, moderate floods, prevent soil erosion, improve water availability and increase fuel, fodder and agricultural production on a sustained basis.

6. Alternate Land use :

All drylands are not suitable for crop production. Some lands may be suitable for range/ pasture management and for tree farming, dryland horticulture and agro-forestry systems including alley cropping. All these systems which are alternative to crop production are called as alternate land use systems. These systems help to generate off-season employment in mono- cropped dryland and also, minimize risk, utilize off-season rains, prevent degradation of soils and restore balance in the ecosystem. The different alternate land use systems are alley cropping, agri-horticultural systems and silvi-pastoral systems which utilize the resources in better way for increased and stabilized production from drylands.

The following factors have to be considered while selecting IFS in rainfed areas. Soil types, rainfall and its distribution and length of growing season are the major factors that decide the selection of suitable annual crops, trees and livestock components. The needs and resource base of the farmers also decides the selection of IFS components in any farm.

1. Grain crops : According to soil type we can select suitable crops.

   For black soil :

Cereals	:	Maize
Millets	:	Sorghum, bajra
Pulses	:	Greengram, blackgram, redgram, chickpea, soybean, horse gram

Oilseeds	:	Sunflower, safflower
Fibre	:	Cotton
Other crops	:	Coriander, chillies,
For red soil		
Millets	:	Sorghum
Minor Millets	:	Ragi
Pulses	:	Green gram, red gram, soybean, horse gram, cowpea
Oilseeds	:	Groundnut, castor, sesame

2. Forage crops :
   For black soils
   Fodder sorghum, fodder bajra, fodder cowpea, Rhodes grass, *Elusine sp.*, Thomson grass
   For red soils
   Fodder sorghum, fodder bajra, fodder ragi, fodder cowpea, Stylo, siratro, marvel grass, spear grass and vettiver

3. Tree species :
   For red gravelly/ sandy red loam soil
   Tamarind, *A. tortilis, A .mellifera*, Neem, Hardwickia binata, Ber, Indian Gooseberry, Casuarina, Silk cotton etc.,
   For black soils
   Acacia nilotica, A.tortilis, A.albida, Neem, *Holoptelia integrifolia, Hibiscus tilifolia, Gmelina arborea,* Casuarina, Subabul and *Adina cordifolia*

4. Livestock and birds :
   Goat, sheep, pigeon, rabbit, quail and poultry.

Agronomic approaches for increasing the overall productivity and sustainability of IFS in rainfed area-

1. Adoption of improved cropping system according to the rainfall and soil moisture availability.

2. Selection of suitable grain crop species, tree species that supply pods/leaves for a longer period or throughout the year.
3. The surplus fodder leaves, crop residues etc. during the rainy season should be preserved as silage/hay for lean season (summer).

Integrated farming system model for Rainfed system

To overcome complete failure in the rainfed areas through traditional crop activity being practiced, integrating different enterprises and utilizing the biomass buildup have been identified as a successful venture to give regular income to the rainfed farmers. There is a good scope for getting required biomass even with the available erratic seasonal rainfall, to the allied enterprises likely to be integrated *viz.*, goat, buffalo, pigeon, rabbit, etc. The outcome of these enterprises will be an alternate source for protein, CHO, fat, minerals, vitamins and energy. Drought tolerant perennial forest wood /timber value trees can also be raised utilizing the rainfall received round the year and can be a good source for valuable fuel wood or timber after some years.

Similarly, drought tolerant perennial horticultural fruit crops can also be raised utilizing the rainfall received round the year and thus could help in improving the income of the resource poor rainfed farmers. The integrated farming system when implemented properly in the rainfed areas throughout the country, the present contribution from net cultivated rainfed land *viz.*, (42 per cent) can be doubled without any difficulty. The linkage of other enterprises *viz.*, goat, buffalo, pigeon, rabbit, etc. will also provide good amount of organic source of nutrients to the soil. If we could improve the nutrient status of the existing rainfed soils through said linkages; it could enhance the yield substantially, with the prevailing conditions of the rainfed area.

1. Crop + goat

An integrated farming system study involving grain crop, fodder crop, fodder trees, perennial grasses and goat rearing in an area of one hectare of rainfed land was carried out at Coimbatore from 1987-1992. Generally, in dryland farmers raise only fodder sorghum yielding 3 to 10 tonnes of fodder/ha depending upon the rainfall. In the integrated approach, the cropping pattern was modified by including both sorghum grain crop (0.2 ha) and sorghum fodder crop (0.2 ha). To meet the fodder requirement of goats, 0.2 ha of land was raised with subabul and Cenchrus ciliaris, a pasture grass as an intercrop. Trees like *Acacia Senegal* and *Prosopis cinerana* were raised in 0.20 ha. The goat unit comprised of Tellichery goats 20 eves and 1 buck. The results revealed that through short duration field crops and perennial crops the feed requirement for one productive unit consisting of 20 eves and one buck for all the 365 days can be met. After 5 years, the perennial fodder trees could bear the shock and would yield sufficient quantum of lopping to supplement the feed requirement of 21 adults along with millets, legumes and perennial grass linked. The Tellicherry goat will be a good breed to build up body weight for every unit of feed secured through different sources under rainfed condition. It is a dual purpose animal, where it gives 80 to 100 ml of milk after satisfying the full requirement of dependent kids on it every day. Twenty productive females could give 45 kids per annum. Each kid at the time of weaning will weigh around 12 kg. Moreover the unit of 21 animals with different stages of kids under deep litter system would give 11.2 t of valuable manure. This, when applied to the soil, will not only be an excellent source of primary, secondary and micro nutrients for the crops but also absorb more moisture, retain in the soil and releases to the crop appropriately for better yield. The net income from the farming system was Rs.5671 /ha/ year and that of control Rs.1919 /ha/ year. Out of the total income from the integrated farming systems, 59 per cent was from goat rearing. The additional net income realized from integrated terming system was Rs.3752 /ha/year as compared to cropping alone. The additional employment gained through integrated farming system over cropping was 314 man days/ha/year. The organic manures like, litter from the goat unit can readily be used for soil application, and thus will help in enriching the soil. Goat droppings are found to be a good energy source, which can also be linked with biogas unit before it is utilized as manure. This will generate good volume of gas (22 kg of goat dropping will generate one cubic meter of gas as against 30 kg of cattle dung) as well as enhance nutrient availability. Thus, through recycling of organic in the Farming Systems approach, the potential of each produce can be exploited to a greater extent. (Note - The values of income and cost in this experiment would be multiple in present situation)

2. Crop + Tree + Goat

Conventional cropping system with sole sorghum was compared with *Allanthus excelsa*+ crop+ goat, *Ceiba pentandra*+ crop+goat and *Emblica officinalis*+ crop+ goat to identify the suitable component linkage. The cropping systems included were grain sorghum+ cowpea, fodder sorghum+ cowpea and Cenchrus glaucus each in 0.33 ha in integrated farming systems and the remaining 0.01 ha was allotted to the goat component. One unit of Tellichery goats, consisting five females and one male was included in the system. Three tree species *viz., A. excelsa, C. pentandra* and *E. officinalis* were evaluated for their performance under dryland situation to evaluate the suitable in situ moisture conservation practices and nitrogen management on yield of crops in the integrated farming system. Experimental results on integrated farming system revealed that (i) integration of sorghum+ cowpea (grain), sorghum+ cowpea (fodder) and *C. glaucus* each in 0.33 ha intercropped in *E. officinalis* with Tellichery goat component (5+1) in 0.01 ha resulted in higher productivity, economic returns and provided better employment opportunity and improved soil fertility than raising sole sorghum alone (ii) growth of *E. officinalis* was better as compared to other trees under vertisol dryland situation, (iii) coir pith mulching and pitcher irrigation increased the tree seedling growth than the control, (iv) tied ridges conserved more moisture and improved the productivity of the crops, (v) application of 50 per cent N through fertilizer and 50 per cent N through goat manure increased the productivity, enhanced the soil fertility and provided better opportunity for recycling of manure to the crops.

Integrated, silvipastoral based farming system

A research on three components including silvipasture, dairy and goats in one-hectare farm for growing Silvipasture components in an intercropping situation was conducted in TNAU, Coimbatore. The crops *viz,* Subabul *(Leuceana leucocephala)*, gliricidia *(Gliricidia maculate)* African Senegal *(Acacia senegal)* and casuarina *(Casuarina equisetifolia)* were raised in main plots and annual fodder crops *viz.*, sorghum (cv. K 10) horsegram (Col), Kolukkattai grass *(Cenchrus ciliaris)* in sub plots as an inter crop in between the perennial fodder trees. The animal component consisted of dairy unit with one milch animal and gotary unit (1 buck + 5 does) of Tellicherry breed. The recycling of fodder crops and farmyard manure were practiced for generating optimum income from this system. The maximum grass legume fodder production of 18.63 t/ha was registered and recycled for animal feeding. Among the animal components, rearing goats recorded higher income followed by milch animal. Therefore inclusion of goat and dairy units generated good income from the first year onwards. The silvipastoral system also generated employment for men. The integrated farming system provides excellent opportunity for organic recycling and it reduces the farmers dependency on external or market purchased inputs. It offers good scope for recycling of crop components to the animals and animal waste to the crop components. Such system can be converted into ecological farms with high economic returns.

Fish Farming as a component of IFS in rainfed area

Fish farming in watershed area :

Every watershed essentially has one or more than one water bodies in it. These water bodies may vary in size from a small dug out area popularly known as village pond or tank (0.01 to 5.0 ha) to a small reservoir (less than 100 ha)., Separate fishery management is required for different size of water bodies these water resources offer immense scope and potential for generating additional income to an individual farmer, to a community or a village depending on the size of water body.

Small water bodies :

Fish culture in small water bodies may be termed extensive where fish seed (fingerlings) is released and reared with few or no modification of the ecosystem. Small water bodies are shallow and biologically more productive. They are infested with various aquatic weeds and may be seasonal, annual or perennial. Dissolved oxygen is deprived from Photosynthesis as there is no wave action. Through complete fishing, no adult fishes are left for auto-stocking of fish seed and manipulation of water ecosystem is possible for fish culture.

Very small water bodies (Village ponds) :

Such ponds can suitably be dug out where soils permit less drainage. These ponds have usually multipurpose uses (drinking, cattle washing, bathing, irrigation, domestic uses etc). Traditional culture of fish in these ponds yields 600 kg/ha/year. The new scientific approach Yields 3-10 tons fish/ha/year, which involves composite culture of six fish species which are not only compatible but utilizes all available food in a pond. Ponds of 0.1-2.0 ha area with depth of 1.5-2.5 m and rectangular in shape are suitable for such cultures.

B) Integrated farming system for arid region

Indian arid zone constituting 12 percent of the total area of the country. The arid region of India is spread over 38.7 million ha area, out of which 31.7 m ha is under hot and region and 7 million ha under cold arid region (Lahul and Spti valley in Himachal pradesh and Leh and Kargil in Jammu and Kashmir). The hot arid region occupies major parts of north western India (Rajasthan and Gujarat) (28.57 m ha) and occurs in small pockets (3.13 m ha) in south India (Bellery and Tumkur districts of Karnataka and Anantpur district of Andhra pradesh).

Environment :

Sods are dry for most part of year having aridic moisture regime and hypothermic thermal regime. High temperature increases evaporation and transpiration to an extent where water loss is considerable. The abundant light and high light intensity cause greater stomatal opening and lead to greater transpiration. Dry winds remove moist air around the plants which also increase transpiration. Ground water is deep, and often brackish. Soils are course textured and covered with sand dunes. Low available water capacity, low tenthly, high salinity, calcareousness, gypsiferous nature of soil are major soil constraints. Frequent draughts results in failure of crops, migration of animal and human population. Low and erratic annual precipitation (150-400 mm), high solar incidence (450-500 cals/ cc^2 /day) and high wind velocities (20-21 km/ hr) resulting in a high PET (6 mm day) and a consequent high aridity index of 78 %. The soils are loamy sand with low organic matter content, high infiltration rate and have a very poor moisture storage capacity.

Average size holding of the farms in the region is large of which 80% is cultivated. The subsistence farming included mixed cropping with rearing of sheep, goat and other livestock animals. In order to improve the production from the arable farming, the adoption of economically viable dry farming technology for crop production will improve the risk bearing capacity of the small farm. The improved dry farming technology consists of efficient management of rain water, suitable tillage and seeding practices, efficient crops and their varieties matching rainfall pattern, appropriate cropping systems and integrated soil fertility and pest management.

In situ moisture conservation, inter-row / inter-plot water harvesting, run off collection and its recycling for life saving irrigation during drought and incorporation of bentonite clay as sub-surface moisture barrier to avoid deep percolation losses. Among the tillage practices, deep ploughing in alternate years or use of sweep cultivator every year gives a satisfactory seed bed preparation and the sowing of the crop may preferably be done with a seed drill having a good metering device.

Intercropping systems comprising grain legumes (green gram/ cluster bean/ cowpea/ moth bean)+ pearl millet and sesame+ grain legumes and a special system combining grass Centurus ciliaris and Lasiurus sindicus with grain legumes proved to be efficient. Double cropping is also possible following pearl millet-mustard rotation in good and extended monsoon seasons. In the event of delayed onset monsoon, allocation of land may be done in such a way that pulses occupy the major areas and for satisfactory production of pearl millet (staple food) can be achieved by transplanting. In the event of break in monsoon early in the season, on the revival of rains, gap filling of pearl millet by transplanting to make the stand good and complete removal of weed to conserve the moisture may be resorted to. If the event of drought occurs late in the season, reduction of plant population by thinning and protective irrigation from the harvested water could be taken up.

Cropping system for arid regions :

a) Pearl millet based cropping system : Pearl millet is the most important kharif crop of the region. Pearl millet is either grown as monoculture or in pearl millet- fallow rotation with 100% cropping intensity. Cultivation of pearl millet year after year in the same land reduces the productivity. Pearl millet- green gram and pearl millet- cluster bean rotation is more advantageous than pearl millet- pearl millet rotation. Intercropping of pearl millet with green gram produces more yield than with sole crop of pearl millet.

b) Pulse based cropping system : Some of the kharif pulses like green gram, moth bean and cowpea are important pulses grown in the arid areas. Cluster bean is a grain legume with export potential because of its gum contents. They are generally grown mostly in second and last week of July.

c) Oilseed based cropping system : Sesame, groundnut and castor are the main oilseed crops grown during the kharif season in the arid areas. Rapeseed, mustard and taramera are the main oilseed crops grown during the rabi season. These crops are either grown on conserved moisture of the late monsoon rains or under irrigated conditions.

Other components of Farming system in arid area :

Horticulture :

A number of fruit crops which can be grown successfully in arid region such as- ber, pomegranate, custard apple, caronda *(Carissa carandas)* and amla as potential horticultural crops for this region. Out of these ber is found be the most promising one and accepted by the farmers of the region since it can be grown successfully even on marginal drylands. Agri- horticulture on drylands possible with ber and grain legumes. This system is desirable in stabilizing income of small farmers.

Agroforestry :

In the situation where crop yields are not only low but uncertain, there agroforestry is the main answer where the object is integrating of tree planting with farm practices and forestry acts as foster mother to agriculture. A farmer needs firewood for cooking and domestic, heating, timber for house construction and agricultural implements, fodder for livestock and manure for his fields. By planting suitable species of trees on his land, the farmer can be self sufficient to these essential needs. With an appropriate choice species of trees and the adoption of sound silvicultural practices the farmer can considerably augment his income without affecting agriculture. *Acacia tortilis, Acacia albida, Prosopis cineraria, Zizyphus nummularia, Albizia lebbeck,* etc. are the suitable species for farm forestry.

Agri-silviculture :

Tree species like *Acacia nilotica, A. Senegal, Tecomella undulate, Hardwickia binata and C. mopane* could be useful components for agrotorestry systems in arid regions. These tree species are having economic, fodder and fuel value and thus could be used for agroforestry purposes. Pulse crops *viz.* green gram, cluster bean, moth bean, etc can grow under these tree species. Research has shown that, in infertile sandy soils, crop yield of groundnut and millet increased 500-900 kg-ha directly under *F. albida* foliage. In addition to a 50-100% increase in soil organic matter and nitrogen content, soil microbiological activity and water holding capacity also improved. Crop yield of sorghum and castor is also as good as sole crop when grown with *F. albida, Acacia ferruguea and P. cineraria.*

Agri- horticulture :

The legume crop production of cowpea, cluster bean, green gram, etc. can successfully implemented as intercropping with arid fruit crops such as- ber and amala.

Horti-pasture :

Ber *(Zizipphus nummularia)* is another Impotent top feed species. Even in drought years when the crops fails, the top feed of this species comes to the rescue of farmers animals. In sandy grass lands, plantation of *Z. rotundifolia and Z. nummularia* each with 3 densities 280, 140 and 70 plants/ ha with *Cenchrus ciliarist* as pasture grass gave forage yield varying from 624 to 844 kg/ ha. In hortipastural system survival and productivity of fruit crops guava and custard apple was much better with legume *Stylosanthus hamata* and *C. ciliaris.*

Silvi-pasture :

Adoption of silvi- pasture system is the way to continuous supply of fodder, fuel, wood and other associated products. In this system forage grasses are grown in combination with trees and shrubs. The interspaces between the rows of trees are utilized for growing nutritious grasses and grass legume mixtures. The animals are permitted to graze underneath the trees. Tree spacis should be fast growing, hardy and having wild adaptability to different soils and agroclimatic conditions. *Acacia tortilis, Colophospermum mopane* and *Hardwickia binata* can be planted in association with *Centurus ciliaris* grass.

Animal husbandry :

The soil and climatic conditions of the desert is considered more suitable for livestock farming than crop farming. During the drought years while agricultural production falls to less than 10 of the production of a favorable year, the production of milk and wool is still over 50% of that of a good year. Besides with capable of withstanding extremes of climatic and nutritional stresses, the desert livestock also benefits from seasonal migration. The productive breeds of goats and sheep can provide major sustenance to the arid farmers.

Nursery raising techniques

Raising of ber plants in polythene tubes (25.4 x 10.2) cm with 300 gauge thickness) by 'T' budding method was found successful for mass multiplication of plants. Raising of pomegranate plants polythene tubes (both end open) by simple method (stem cutting) is the easiest method found to be best for mass multiplication of plants.

Post harvest technology

With the introduction of new and improved varieties of fruit crops the area and production were increased. Therefore with the preparation of beverages, jam jelly, candy, etc. the post-harvest losses of fruits which are having very short shelf life, could be reduced to a considerable extent. Following processed products can be prepared with fruits-

Amla - jam, pickles, candy
Bel - jam, squash
Ber - Dehydrated ber, jam, squash
Date palm - khajoor
Pomogranate - Anardana, jelly, squash.

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Chapter - 7

Integrated Farming System for Coastal and Lowland Areas

A) Integrated Farming System for Coastal Areas

Coastal agro- ecosystem comprises not only shoreline ecosystems but also the upland watersheds draining into coastal waters and the near shore sub littoral ecosystems influenced by land based activities. India has an 7516 km long coastline. Its peninsular region is bounded by the Arabian Sea, the Bay of Bengal and Indian Ocean. It has two distinct major island ecosystems, the Andaman and Nicobar group of islands in the Bay of Bengal and the Lakshadweep islands in the Arabian sea. With an estimated 1.2 million hectares of brackish water area availability for the purpose, coastal aquaculture is emerging as a major production of about 75000 tonnes of shrimp. Attention is also being paid to cultures of fishes, other species of shrimps, crabs, lobster and sea weeds. In west Bengal, it includes Bengal basin and north Bihar plains. Length of growing period is 210-240 days. In coastal areas, soils are very deep, fine loamy and poorly drained. These are cultivating for rice, wheat, potato and oilseed crops. However, there is scope for fishing, apiary and duckery in these areas. These areas are profitably used for growing coconut, rice, tapioca, cashew, groundnut, arecanut, millets, mango, pine apple and rubber

Almost the entire coastal area of the country excluding the north Gujarat coast receives a normal annual rainfall of more than 100 cm. The west coast gets more than 250 cm. More than 80 % of the annual rainfall is received during June- September in the states of Karnataka, Maharashtra and Gujarat. In case of West Bengal and Orissa, 70-80 % rainfall is received in the months of May-October. The coastal areas of Tamil Nadu receive only about 30 % of rainfall in the same period and the remaining rainfall is received in October- November. Strong wind blows mainly are association with cyclonic storms or depressions along the coasts. The maximum wind speed estimated in the cyclonic storms ranges from 100 to 150 km/hour. There are as many as 600 small rivers on the west coast in Gujarat, Maharashtra, Karnataka and Kerala.

Components of Farming Systems in Coastal Area :

1. Rice based system :

Rainfed upland rice is generally cultivated in 700-1100 mm rainfall zones. Upland rice occupies 7.0 million ha. Shallow lowland ecosystem occupies 8.0 million hectares. Nearly 4 million hectares of rice land with a standing water of 30 -50 cm depth in the field during the crop growth stage (one month) constitute intermediate lowland ecosystem. Deep water rice ecosystem occupies 2.4 million hectares with a standing water above lm depth for a period of about one month causes drastic reduction in yield.

2. Horticultural based system :

The coastal ecosystem offers vast scope for a wide variety of fruit and vegetables crops, spices and medicinal plants. Plantation crops such as coconut, arecanut, oilpalm, cashew, cocoa, spices (black pepper, cardamon, ginger, turmeric, cumin, coriander, fennel, fenugreek), medicinal plants and nearly all types of vegetable crops.

3. Silviculture :

Mangrove is one of the most important sources of timber, fuel, railroad, ties and tannin in the tropics. It also has resins, which are used as plywood adhesives and the bark, leaves, shoots and roots contain dyes. The important species of mangrove are *Heritiera* (boat building, fuel), *Amoora cuculata* (wooden toys), *Aegiatilis rotundiflora* (extraction of high grade salt after burning), *Avicennia* (fuel wood), *Exocoecaria agallocha* (match boxes), *Xylocarpus granatum* (pencils) and *Salicomia brachiata* (source of sodium carbonate).

4. Agroforestry :

It is a collective name for a land use system in which woody perennials, trees (including fruit trees), shrubs, bamboo etc. are deliberately combined on the same and management unit with herbaceous crops and animals either in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions among the different components. It has good prospect for the coastal ecosystem.

5. Aquaculture :

Intensification and diversification of aquaculture practices are recent trends to increase production with great scope for further improvement. In most of the coastal areas, the climatic conditions permit at least 2-3 crops a year. Coastal aquaculture systems like Ganga estuarine system. Mahanadhi estuarine system, Krishna-Godavari and Kolleru lake system, Kerala backwater system and Narmada system are important resources offering scope of increasing the aquaculture production. In West Bengal and Kerala, both the indigenous and exotic carps are cultivated.

6. Livestock based :

Milk production in coastal states constitutes 38.9% production of India. There is considerable production in these areas, where it is constrained due mainly to poor health of the cattle breed under unfavorable climate, restricted fodder availability and lack of organized cooperative movements in most parts. In coastal areas with water bodies present predominantly duck should form a popular poultry constituent.

Rice-Based Fish Farming

Rice-based fish farming is the main source of earning in many parts of the world and the net productivity from RFC is reported to be higher than rice monoculture. Rice- fish culture (RFC) under either capture systems or culture systems is a low-cost sustainable practice to obtain high value protein food and minerals. The Integrated rice-fish farming can help Bangladesh keep pace with the current demand for food through rice and fish production but requires greater encouragement if it is to realize its full potential.

Rice + Fish +Poultry Farming System

Field experiments conducted at Annamalai University experimental farm. Annamalainagar during 2011-2012 revealed that the integration of Rice + Fish + Poultry with 100% of normal recommended dose of fertilizer performed superior with the highest grain yield of 5.89 t/ ha and net return of Rs. 1,78,110. Integration of Rice + Fish + Poultry + No fertilizer has least net return Rs1,72,453. The results of the study indicate that integrating fish culture and poultry rearing offers a sustainable option in rice farming in terms of enhanced returns, soil fertility and reduced pest incidence (Meenakumari, 2012).

Rice +Duck+ Goat Farming System

Field experiments conducted at Annamalai University experimental farm, Annamalai nagar during 2011-2012 revealed that Goat grazing plus duck scavenging coupled with conoweeder plus one hand weeding was beneficial in increasing the grain yield of rice (4.16 t/ha) which was found best economically beneficial and practically feasible farming system model.

B) Integrated Farming system for low lands

The low farm productivity in lowland can be upgraded to potential level through adaption of integrated farming system. Integrating rice and fish in low-lying wetland would improve the farm productivity through recycling of nutrients. In addition, the system provides incentive for farmers to reduce the use of chemical fertilizers and pesticides. This could be managed by proper integration of cropping and fish culture with the available farm resources. Vertical expansion by integrating appropriate farming components requiring lesser space and time and ensuring higher total productivity of the lowland is the only alternate option left out. The sustainable farming systems should be economically viable and ecologically compatible encompasses with higher productivity. This could be possible through optimal crop and other enterprises link in accordance with the farm resources available in the farming system.

Rice+ poultry+ fish+ mushroom farming system :

The research was conducted to evaluate the farming systems with rice- poultry- fish- mushroom to increase the income of the small and marginal farmers of irrigated low land areas at Coimbatore during 1987-92. This model of farming system is developed for small and marginal farmers on 0.40 ha area which includes following components-

Cropping system : Rice-rice- maize (0.16 ha), rice- rice-groundnut (0.10 ha) and rice- rice - sesame (0.10 ha)

Fish culture : Fish pond to an area of 0.04 ha with a depth of 1.5 m. is used to raising the species Silver carp (60 No. as surface feeder), Catla (60 No. as surface feeder), Rohu (60 No. as column feeder), Mrigal (45 No. as bottom feeder), Common carp (45 No.

as grass feeder) and Grass carp (30 No. as grass feeder). Fish are ready for harvesting in ten month.

Poultry farming : A poultry shed having plinth area of 2.2 m^2 is provided with wire mesh (3 × 3 mm) to facilitate free falling of poultry droppings into the fish pond. About 20 numbers of (500/ha) 18 weeks old bapkock chicks can be kept in the poultry shed. The birds are fed as prescribed for different growth and production phase of the fowls. The feed components other than mineral mixture shell grift, molasses and fish meal can be utilized from the crop component. Rice bran maize flour, groundnut cake, sesame cake, alfalfa meal and ill filled paddy grains produced from the crop component of the IFS are used for preparation of the poultry feed. The alfalfa meal which used for poultry feed can be raised around the fish pond. The birds will started laying eggs around 22 week and will be culled at the age of 72 week when the egg production becomes uneconomical.

Mushroom production : Paddy straw is available plenty in the lowland area, the mushroom, *Plurotus spp.* (Paddy straw mushroom) can be effectively grown for gaining additional income and employment. A mushroom shed with dimension of 5 × 3 m can be constructed with locally available materials to take up the desired production level of 1.45 to 2.0 kg mushroom per day.

Research work has shown that an average net income of Rs.53,000/- can be obtained from this type of farming system in lowland area with fulfilling the family needs of small and marginal farmer.

Crop + dairy + fishery farming system :

This model of proposed integrated farming envisaged a change in cropping pattern over conventional cropping and inclusion of dairy animas and fish production. The changed cropping pattern advocated a reduction in area under rice based cropping system and reallocating the diverted area for millets, cotton forage grass, forage legume and fish pond. Rice- rice- soybean (bunds)- black gram in 0.4 ha, finger millet + sunflower (border)- fodder maize+ cowpea-cotton + greengram in 0.2 ha, napier hybrid fodder grass in 0.3 ha fish pond in 0.04 ha and cattle shed for 3 Jersey cows and 2 work bullocks in 0.06 ha are allocated in this type of model.

The research conducted at Killikulam in Tamil Nadu proved that, this integrated farming system model provides 100.7% more income than conventionally implemented cropping system.

CHAPTER - 8

Integrated Intensive Farming Systems (IIFS)

With increasing population there is a steady decline in the per capita availability of land and water. This makes higher productivity per unit of land and water imperative. Because of the environmental problems linked with traditional Green Revolution technologies, higher productivity per unit of land and water must come from somewhat different production pathways. We have to produce more, but will have to do it differently with avoiding the harmful effects of mineral fertilizers and chemical pesticides as in green revolution. Inadequate purchasing power of large sections of people is due to lack of productive employment. Modern industry is often not labour intensive and new jobs have to be found in the farm and non-farm sectors in rural areas. Productivity improvement is an economic necessity because under conditions of small holdings, income of family can be enhanced only through greater marketable surplus and multiple sources of income. Productivity improvement is also an ecological necessity since otherwise the remaining forests may be cleared for crop cultivation.

Concept of IIFS :

IIFS involves intensive use of resources of the farm. Intensification is based on techniques which are knowledge based rather than capital intensive based. To the extent possible, market purchased chemical inputs are replaced with farm grown biological inputs. This shift is brought about through integrated farming involving animal husbandry, fisheries and agroforestry. This also provides scope for organic recycling. Through the establishment of biorefineries value is added to every part of plant and animal biomass. On-farm and off-farm employment can then be linked in a symbiotic manner.

Components of IIFS

1. Soil Health Care :

Soil health is fundamental in sustainable intensification. Stem nodulating legumes such as *Sesbania rostrata* and incorporating Azolla, blue green algae and other sources of symbiotic and non-symbiotic nitrogen fixation are a part of, the farming system. Vermiculture constitutes an essential component. Besides biofertilizers, improved composting techniques are used for efficient recycling of organic residues. Green leaf manures and small quantities of powdered neem cake are used. These organic supplements prevent loss of fertilizer nitrogen due to denitrification, ammonia volatilization and other process. These bulky organic supplements have to be generated on the farm itself to avoid transportation costs over long distances.

2. Water Harvesting and Management :

Included in the agronomic practices are measures to conserve rain water so that it can be used in a conjunctive manner with other sources of water. Final ploughing across the slope and planting the crop across the slope are a must. Maximum emphasis is placed on *in- situ* moisture conservation, on-farm water use efficiency and adopting drip and sprinkler irrigation to optimize the benefits from the available water. Efficiency, economy and equity in water use are to be ensured through cooperative management of watersheds and command areas.

3. Crop Management :

Integrated nutrient supply is an important component. Plant nutrients can be supplied from different sources *viz.*, organic manures, crop residues, biofertilizers and chemical fertilizers. All possible sources of nutrients are applied and only the balance required by the crop is supplemented with chemical fertilizers. Integrated nutrient supply has to be chosen on the basis of the farming system and the agroecological and soil conditions of the area. Hybrids and high yielding varieties have to be cultivated. It is very important to give very careful consideration to the composition of the farming system. Soil condition, water availability agroclimatic features, home needs, and above all, marketing opportunities will have to determine the choice of crop, farm animals and aquaculture systems. Small and large ruminants have a particular advantage among farm animals as they can live largely on crop biomass. IIFS has to be based on both land saving agriculture and grain saving animal husbandry.

4. Pest Management :

Integrated pest management system forms a component. Antagonistic fungi such as *Trichoderma viride* and other beneficial bacteria like *Pseudomonas fluorescence* are used to control a host of pathogenic infections in a wide variety of crops. They can be used for treating the seeds and root dipping. They can also be applied directly to the fields. A wide range of botanical pesticides such as neem derivatives, custard apple seed oil, and a host of decoctions of local plants are used by farmers for either repelling or eliminating pest. The use of biological control agents such as parasites and predators; are used in of place of toxic pesticides. A number of viral and bacterial agents are also available for effective plant protection, other cultural practices and companion planting and trap cropping and the use of pheromones and light traps also come in handy.

5. Energy Management :

Energy is an essential input. Every effort should be made to harness biogas, biomass, solar and wind energies to the maximum extent. Solar and wind energy is to be used in hybrid combinations with biogas for farm activities such as pumping water, drying grains and other farm produce.

6. Post Harvest Management :

Best available threshing, storage and processing measures should be adopted. Value-added products from every part of the plant or animal have to be produced. Post-harvest technology assumes importance in the case of perishable commodities such as fruits, vegetables, milk, meat, eggs, fish and other animal products. Growing urbanization leads to diversification of food habits. Therefore, there will be an increasing demand for animal products and processed food. Agro processing industries have to be promoted on the basis of consumer demand. These processing industries should be promoted in villages to increase employment opportunities. Government has to make major investment to provide storage facilities, roads and communication, sanitary and phyto-sanitary measures. Bin- refineries concept and the effective use of crop residues would be meaningful and income generating exercises. Grain losses can be avoided through proper drying using solar dryers and storing the produce in properly designed storage structures prevents losses due to rodents, insects and fungal attacks. The crop residues and by-products can be used for making a variety of finished products at the village itself. This will generate off-farm jobs.

7. Information, Skill Organization and Management Empowerment :

A meaningful and effective information and skill empowerment system is necessary for the success of IIFS.

Organization and management are key elements and depending on the area and farming system, steps have to be taken to provide small producers the benefits of scale in processing and marketing.

IIFS is best developed through participatory research among scientists and farmers. IIFS can succeed if it is human centered rather than a mere technology driven programme. The essence of IIFS is the symbiotic partnership between farmers and their natural resources endowment of land, water, forests, flora, fauna and sunlight. It will be difficult for small farmers to adopt IIFS without appropriate public policy support in areas such as land reform, security of tenure, rural infrastructure, input and output pricing and marketing. IIFS methodology shows the path to achieving the goal through agricultural intensification, diversification and value addition in an ecologically, economically and socially sustainable manner.

CHAPTER - 9

Cropping Systems

Cropping system :

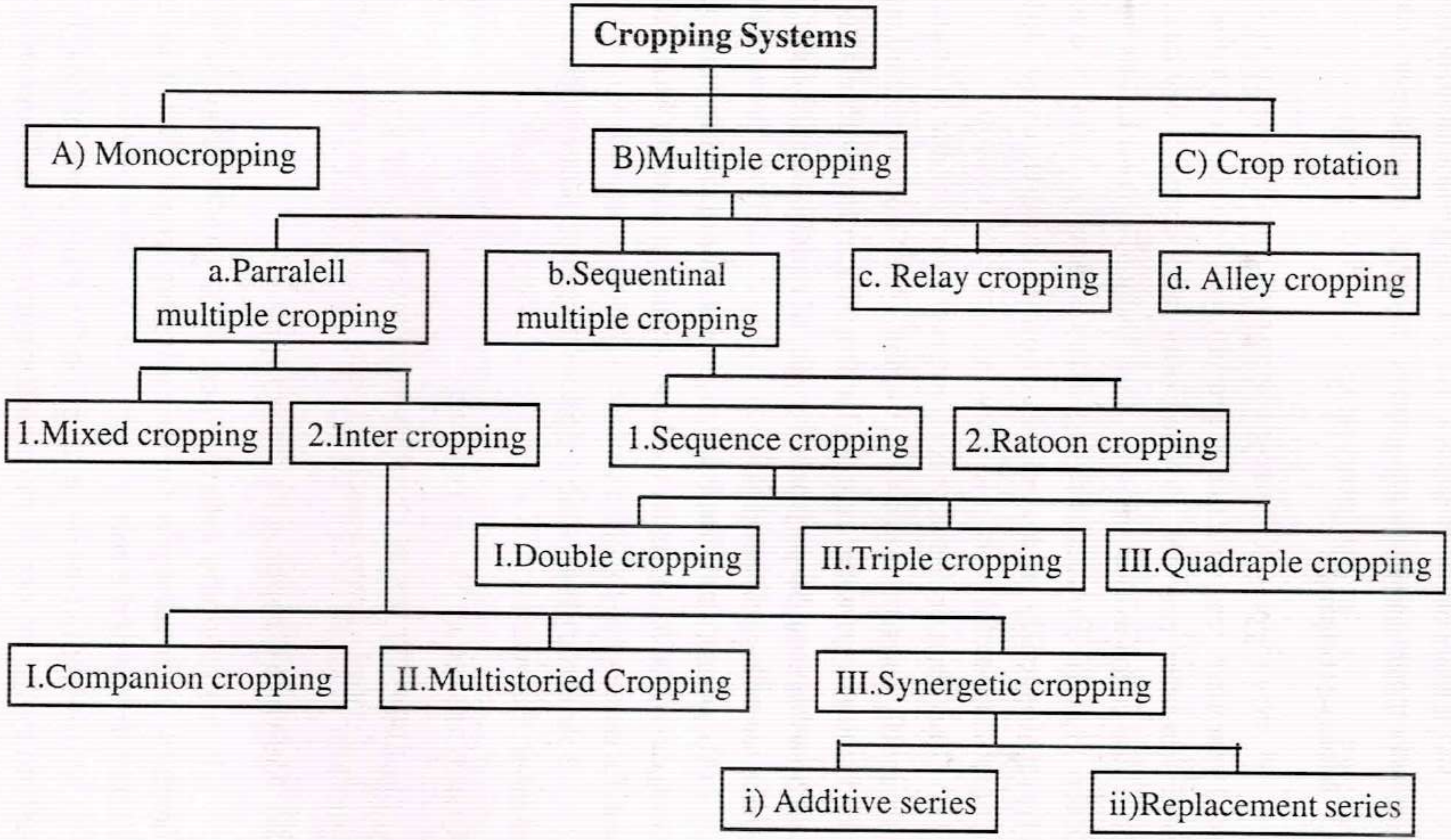
A cropping system refers to the principles and practices of cropping and their interaction with farm resources, technology, aerial and edaphic environment to suit the regional or national or global needs and production strategy.

Cropping system represents Cropping patterns used on farm and their interactions with farm resources, other farm enterprises and available technology which determine their makeup.

Cropping pattern :

Cropping pattern means the proportion of area under various crops at a point of time in a unit area. It indicates yearly sequence and spatial arrangement of crops & fallow in an area.

Classifications of Cropping System :



Depending on the resources and technology available, different types of cropping systems are adopted on farms, which are as below-

A) Mono-cropping :

Mono-cropping refers to growing only one crop on a particular land year after year. Practice of growing only one crop in a piece of land year after year e.g. growing only rabbi crops in dry lands or only said crops in diary lands (Lands situated in river basins which often remain flooded during rainy season). This is due to climatologically and socio economic conditions or due to specialization of a farmer in growing a particular crop.

Groundnut or cotton or sorghum is grown year due to limitation of rainfall. Tobacco is grown in Gunter (A.P.) due to specialization of a farmer in growing a particular crop. Rice crop is grown, as it is not possible to grow any other crops, in canal irrigated areas, and under water logged conditions.

Monoculture : Practice of repetitive growing only crop irrespective of its intensity as rice-rice-rice in Kerala, West Bengal and Orissa.

Sole Cropping : One crop variety grown alone in pure stand at normal density.

Disadvantage in Monocropping

1. Improper use of moisture and nutrients from the soil
2. Control of crop associated pests and weeds become a problem

B) Multiple Cropping or Polycropping :

It is a cropping system where two or more crops are gown annually on the same piece of land using high input without affecting basic fertility of the soil.

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

a. Parallel multiple cropping :

Under this cropping two or more crops are grown simultaneously in the same land which have different growth habits and have a zero competition between each other and both of them express their full yield potential. e.g.

1) Green gram or black gram with maize. 2) Green gram or soybean with cotton.

Subtypes of Parallel multiple cropping :

1. Mixed cropping :

Mixed cropping is growing of two or more crops simultaneously on the same piece of land seeded either after the seeds of the crops intended to be grown mixed or sowing alternate rows in various replacement ratios. This may or may not have distinct row arrangement and the mixed plant community faces inter and intra row competition with a different plant type/variety. The basic objective in mixed cropping is minimization of risk and insurance against crop failure due to aberrant weather conditions. In inter-cropping systems, pressure of plant density per unit are is more than that in a sole cropping system, while in mixed cropping the plant population pressure is generally equal to sole cropping and in some cases it may even be less than sole cropping system.

2. Inter Cropping :

Growing of two or more crops simultaneously on the same piece of land with a definite row pattern e.g. growing set aria + red gram in 5 : 1 ratio i.e. after every 5 rows of setaria one row of red gram is sown. Thus, cropping intensity in space dimension is achieved.

Multiple cropping in the form of intercropping is predominant in the regions of dry, humid and semi-arid tropics.

The objectives of Intercropping Systems are :

1. Insurance against total crop failure under aberrant weather conditions or pest epidemics.
2. Increase in total productivity per unit land area.
3. Judicious utilization of resources such as land labour and inputs.

Intercropping was originally practiced as an insurance against crop failure under rainfall conditions. At present the main objective of intercropping is higher productivity per unit area in addition to stability in production. Intercropping systems utilizes resources sufficiently and their productivity is increased.

When two crops are to be grown together, they are chosen in such a way that there is variation in their growth duration. The peak periods of growth of the two crops species should not coincide.

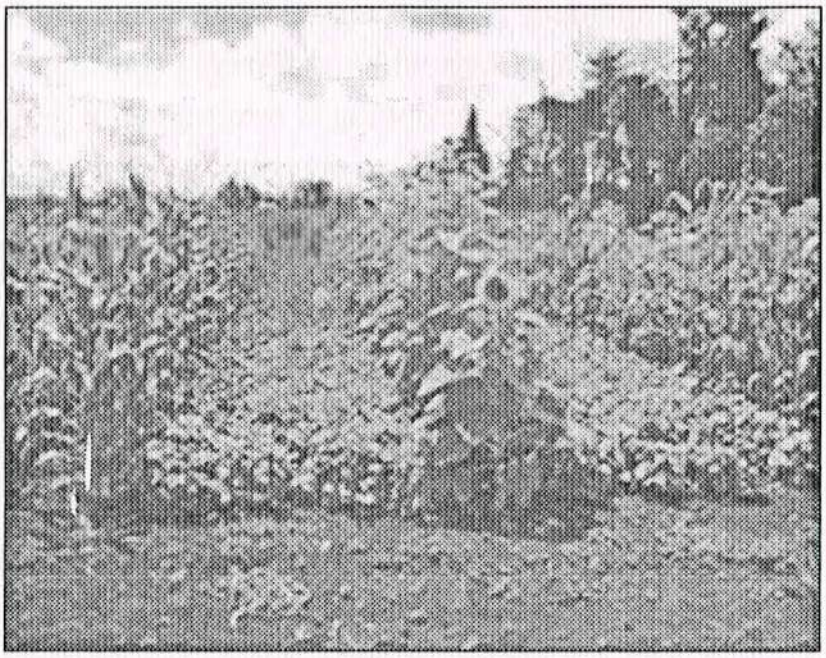


Fig. 1 : Intercropping system

In such arrangements, a quick maturing crop completes its life cycle before the other crop starts. Greater differences in maturity and growth demands of the crop components, more opportunity is provided for greater exploitation of growth factors and over yielding. This will be achieved either by generic difference in crop species or manipulation of planting dates. Normally short and long duration crops are grown together.

Inter Cropping in Cereals : Inter-cropping with cereal is an excellent way of improving the resource utilization because the cereal utilizes the rainy season resources while late maturing crops exploits the post-rainy season resources such as residual moisture. Sorghum is most commonly inter-cropped with pigeon pea on a variety of soils. Sorghum is harvested after 3 ½ to 4 ½ months and pigeon pea matures in about 6-9 months depending on the genotype.

In monocropping of groundnut climate resources like rainfall, temperature and solar radiation are utilized only rainy season, however when red gram is introduced as an inter-crop, these resources are used up to the end winter season and also benefit of late shower rains.

Soybean is also good compatible companion crop with maize. Pearl millet is a quick tillering and fast growing crop that attains full canopy development within 20-30 days of seedling establishment. It can be inter-cropped with groundnut, black-gram or castor.

Inter Cropping in Pulses : For pigeon pea, short duration grain legumes such as black-gram and soybean are the best companion crops in Peninsular India. Groundnut is also a suitable inter-crop.

Inter-cropping in cotton : It is initially a slow growing crop. Any short duration and fast growing crops such as groundnut, black-gram, green-gram or cluster bean are the compatible companion crops.

Inter Cropping in Sugarcane : Sugarcane is slow growing up to 80-90 days. Since the crop is planted in rows 0.8-1.0 m apart, considerable space is available for inter-cropping. Short duration crops maturing in 80-90 days can be advocated as inter-crops. Black-gram and soybean are found suitable. The green manure, Dhaicha can be sown in the inter-space and incorporated at about 2 months.

For successful intercropping, there are certain important requirements :

1. The time of peak nutrient demands of component crops should not overleap in maize + green gram intercropping system, the peak nutrient demand period for green gram is around 35 DAS while it is 50 days for maize.
2. Competition for light should be minimum among the component crops.
3. Complementary should exist between the component crops.
4. The differences in maturity of component crops should be at least 30 days.

Advantage of Intercropping :

1. Intercropping gives additional yield income/unit area than sole cropping.
2. It acts as an insurance against failure of crops in abnormal year.
3. Inter-crops maintain the soil fertility as the nutrient uptake is made from both layers of soil.
4. Reduction in soil runoff and controls weeds.
5. Intercrops provide shade and support to the other crop.
6. Inter cropping system utilizes resources efficiently and their productivity is increased.
7. Intercropping with cash crops is higher profitable.
8. It helps to avoid inter-crop competition and thus a higher number of crop plants are grown per unit area.

Disadvantages of intercropping :

1. Yield decreases as the crops differ in their competitive abilities.
2. Management of crops having different cultural practices seems to be difficult task.
3. Improved implements cannot be used efficiently.
4. Higher amount of fertilizer or irrigation water cannot be utilized properly as the component crops vary in their response of these resources.
5. Harvesting is difficult.

Types of Intercropping :

i) Companion Cropping : In companion cropping the yield of one crop is not affected by other, In other words, the yield of both the crops is equal to their pure crops. That the standard plant

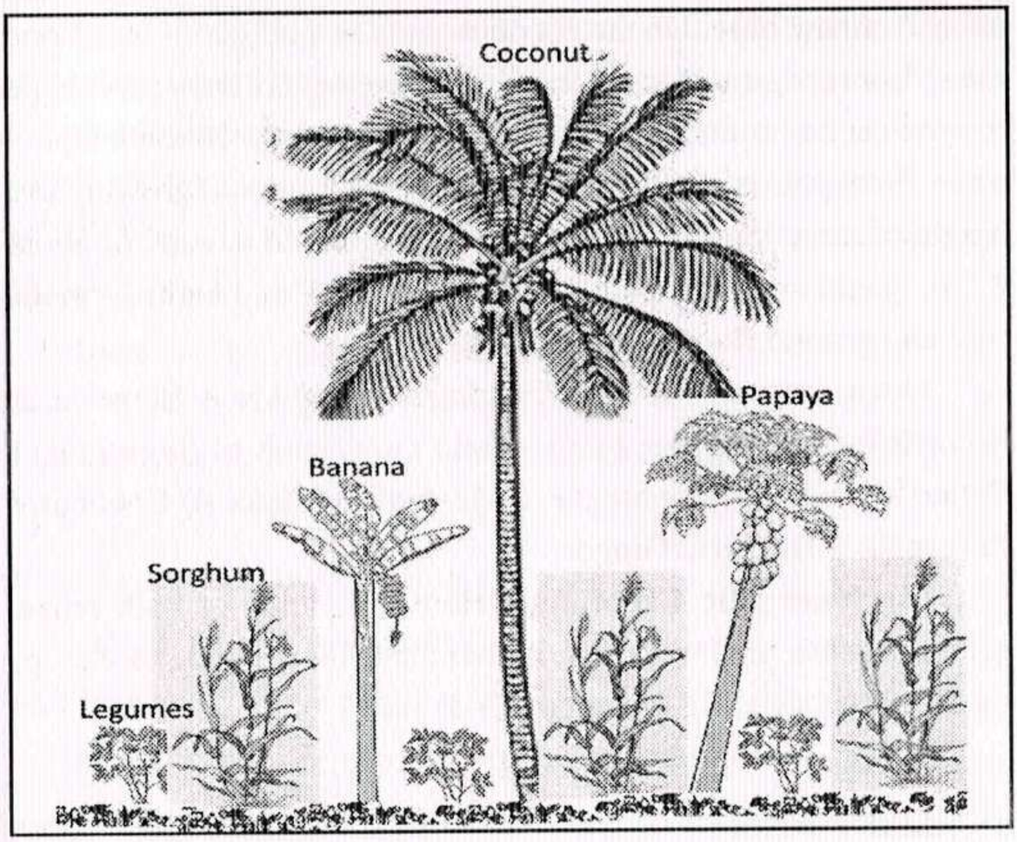


Fig. 2 : Multistoried Cropping

population of both crops is maintained. e.g.1) Mustard, wheat, potato, etc. with sugarcane 2) Wheat, radish, cabbage, sugar beet etc., with potato.

ii) Multistoried Cropping or Multi-tire cropping : Growing plants of different height, rooting pattern and duration in the same field at the same time is termed as multistoried cropping. It is mostly practiced in orchards and plantation crops for maximum use of solar energy even under high planting density. The objective of this system of cropping is to utilize the vertical space more effectively. In this system, the tallest components have foliage tolerant of strong light and high evaporative demand and the shorter components with foliage requiring shade and or relatively high humidity. e.g. Coconut + black pepper + cocoa + pineapple. In this system, coconut is planted with a spacing of 7.5m Rooted cutting of black pepper are planted on either side of coconut about 75 cm away from the base. On the coconut trunk at a height of about one meter from the ground level, the vines of pepper are trailed. A single row of cacao is planted at the center of space between coconut rows. Pineapple is planted in the inter-space. Coconut growing to a height of more then 10 m. Cacao with its pruned canopy of about 2.5 m height and pineapple growing o about 1 m. height form the first and ground floors, respectively.

Other examples are - 1) Eucalyptus +Papaya + Berseem 2) Sometimes it is practiced under field crops such as Sugarcane + Potato + Onion. 3) Sugarcane + Mustard + Potato. 4) Coconut + Pineapple + Turmeric/Ginger.

iii) Synergetic Cropping : Here the yields of both crops, grown together are found to be higher than yield of their pure crops on unit area basis. e.g. Sugarcane + Potato

Subtypes of synergetic cropping -

a) Additive series :

In such type of intercropping one crop is main crop or base crop and another crop is intercrop. Intercrop is introduced into the base crop by adjusting or changing crop geometry i.e. addition of intercrop to the base crop. Here plant population of base crop is same to what recommended population in pure stand whereas that of intercrop is less. Cropping husbandry is according to the base crop. This type of intercropping is prevalent in India and its main objective is to get additiona incom and to cover risk. e.g. sowing of potato into the field of sugarcane in between the rows of cane at 90 cm.

b) Replacement series :

Both the crops are component crops. Neither is the base crop nor is the intercrop. It means the plant population of both component crops is less than their recommended population in pure stand. Such type is widely practiced in western countries.

Component Crop : is used to refer to either individual crops making up the intercropping situation. Intercrop yield is the yield of a component crop when grown in intercropping and expressed over the total intercropped area. (i.e. area occupied by both the crops). A simple addition of both the intercrop yields a combined intercrop yield.

Base Crop : is the one which is plated as its optimum sole crop population in an intercropping situation and second crop is planted in between rows of base crop for obtaining bonus yield from intercrop without affecting base crop yield.

Other types of Intercropping -

Row intercropping : Growing two or more crops simultaneously where one or more crops are planted in rows.

Strip Inter-cropping : Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically.

Difference between intercropping and mixed cropping

S.No	Intercropping	Mixed cropping
1.	The main objective is to utilize thespace left between two rows ofmain crop especially during earlygrowth period of main crop.	Main objective is to get at least one cropunder any climatic hazards (flood, droughtor frost) conditions.
2.	More emphasis is given to themain crop and subsidiary crops arenot grown at the cost of main cropthus there is no competitionbetween main and subsidiary crop.	All crops are given equal care and there isno main or subsidiary crop. Almost all thecrops compete with one another.
3.	Subsidiary crops are of shortduration and they are harvestedmuch earlier than main crop.	The crops are almost of same duration.
4.	Both the crops are sown in rows.The sowing time may be the sameor the main crop is sown earlierthan subsidiary crop.	Crops may be broad casted and sowingtime for all the crops is the same

b) Sequential Multiple Cropping : In this type of mulitiple cropping two or more crops are grown in the same piece of land at different time period or in sequence manner.

1. Sequence Cropping : It means growing of two or more crops in sequence on the same piece of land in a farming year. Crop intensification is only in time dimension and there is no intercrop competition. Depending on the number of crops grown in a year. It is called as double, triple and quadruple cropping involving two, three, and four crops, respectively. e.g. 1. Double cropping : 1.Rice – potato/ mustard 2. Sorghum- gram 3. Soybean-wheat 2. Triple Cropping : 1.Rice- potato-groundnut 2. Cowpea-mustard- jute. 3. Quadruple cropping : kharif groundnut- leafy vegetables- wheat- summer green gram.

2. Ratoon cropping : It refers to raising a crop with regrowth coming out of roots, stem or stubbles after harvest of the crop. It is generally followed in sugarcane, sorghum, pigenpea etc.

c) Relay Cropping : Growing the succeeding crop when previous crop attend its maturity stage or sowing of the next crop immediately after the harvest of the standing crops. Or it is a system of cropping where one crop hands over land to the crop in quick succession. e.g. 1) Paddy-lathers 2) Paddy-Lucerne. 3) Cotton-Berseem. 4) Rice-Cauliflower-Onion-summer gourds.

Overlapping Cropping : In this system, the succeeding crop is sown in the standing crop before harvesting. Thus, in this system, one crop is sown before the harvesting of preceding crops. Here the Lucerne and berseem are broadcasted in standing paddy crop just before they are ready for harvesting.

Advantages :

1. Minimum tillage is needed for relay cropping and primary cost of cultivation is less.
2. Weed infestation is less, as land is engaged with crops year round.
3. Crop residues are added in the soil and thus more organic matter.
4. Residual fertilizer of previous crops benefits succeeding crops.

d) Alley Cropping : Food crops grown in alleys formed by hedgerow intercropping. It is recommended for humid tropics. In semiarid region of India alley cropping provides fodder during dry period. In other words Alley cropping is an agro- forestry system in which fast growing N-fixing stubs are planted as hedgerows. Food crops are grown in alley formed by hedge of trees and shrubs. This system is most suitable for marginal and sub-marginal lands.

The essential feature of this system is that hedge rows are cut back at about one meter height at planting and kept pruning during cropping to prevent shading and reduce competition with field crops. In semiarid regions, alley cropping provide fodder during dry period since mulching the crop with hedge row pruning usually do not contribute to increase crop production.

Advantages of Alley System are as Follows :

1. Provision of green fodder during lean period of the year.
2. Higher biomass production per unit area than arable crops.
3. Efficient use off season rainfall in the absences of the crop.
4. Additional employment during off-season.
5. It serves as a barrier to surface runoff leading to soil and water.
6. Conservation based on objectives following three types of alley.
7. It improves soil fertility and is more remunerative under rain fed conditions.

Systems in Alley cropping :

a) Forage alley cropping.

b) Forage cum mulch system

c) Forage cum pole system.

a) Forage alley cropping : In this system both yield of crop and forage assume importance. Luciana (Squabble), Sesbania are recommended for hedgerow. Pigeon pea or caster crops are suitable for growing in the allies. Crop yields decreases with decrease in the row width.

b) Forage cum mulch system : in these systems hedgerows are used for both forage and mulch. Lapping is used for mulching during the crop season.

c) Forage cum pole systems : Luciana alleys are established at 5-meter interval along the contours. Hedge rows are established by direct seeding and topped every two months at 1.0 m height during crop season and every four months during the off season. A Luciana plant at every 2-meter is allowed to grow in to a pole. Crop yields are usually reduced due to competition from hedgerow.

Classification of alley cropping : According to the purpose for which the alleys are raised, alley cropping may be grouped into :

1. Forage alley cropping.
2. Green manure-cum-mulch alley cropping.
3. Forage-cum-mulch-alley cropping .
4. Forage-cum-green manure alley cropping.

Among them, forage alley cropping is recommended as an alternate land use system for semi-arid regions with main benefit of green fodder production during dry season.

C) Crop Rotation :

It refers to recurrent succession of crop on the same piece of land either in a year or over a longer period of time. Component crops are so chosen so that soil health is not impaired. e.g. cotton-gram, sugarcane- wheat. Or it means growing a set of crop in a regular succession on a piece of land in a specific period of time, with an object to get maximum profit least investment without impairing soil fertility.

e.g. sorghum- gram, groundnut- wheat.

Characteristics of Good Crop Rotation :

1. It should be adaptable to the existing soil, climatic and economic factors.
2. The sequence cropping adopted for any specific area should be based on proper land utilization or it should be so arranged in relation to fields that crop yields can be maintained and also build up organic matter content of the soil.
3. Rotation should contain sufficient area under soil improving crops (legumes) to maintain and also build up organic matter content of the soil.
4. In areas where legumes can be grown successfully, the rotation should provide sufficient average of legumes to maintain "N" supply of the soil.
5. It should provide food grains, pulses, oilseed etc. to family and roughages, fodder to cattle.
6. It should help in control of pests, diseases, and weeds.
7. It should provide maximum area under the most profitable crops adapted to the area.
8. It should be so arranged to make for economy in production and labour utilization.

Advantages of an Ideal Crop Production :

1. There is over all increase in yield of crops mainly due to maintaining physical- chemical properties of soil. Soil fertility is restored by fixing atmospheric nitrogen, encouraging microbial activity (more organic matter) and protecting soil from erosion, salinity and acidity.
2. It helps in controlling insects, pests and soil borne diseases. It also controls weeds. E.g. repeated wheat culture (growing) increases wild oats and phallaris infestation. Similarly growing berseem continuously encourages chicory (kasani)

infestation, but an alternate cropping of berseem and wheat helps in controlling kasani as well as oats and phallaris.

3. Prevent or limit periods of peak requirements of irrigation water. Crops requiring high irrigation if followed by light irrigation, this will not affect or deteriorate the soil physical condition.
4. It facilitates even distribution of labour. Following crop make proper utilization of all resources and inputs. Family and farm labour, power, equipment and machines are well employed thought the year.
5. Farmers get a better price for his produce due to higher demand in local market. So there is regular flow of income over year.
6. Inclusion of crops of different feeding zones (root system) and nutrient requirement could maintain the better balance of nutrient in soil. Growing crops of different root depths avoids continuous depletion of nutrients form same depth. E.g. deep rooted crops take nutrients from deeper zone and during that period upper zone get enriched. Similarly, surface feeding roots take nutrients from upper zone when lower zone get enriched. So growing same crop without rotation results in loss of soil productivity utilized the nutrients from entire soil mass and cost of cultivation is reduced.
7. Diversification of crops reduces risk of financial loss due unfavorable conditions. Diversification of crops means variety of crops can be grown for meeting the domestic needs of farmers and livestock, to reduce risk of market fluctuations, mechanism of farming, growing expensive crops. So all variety of crops are grown in rotation for more benefit.
8. It improves soil structure, percolation and reduces changes of creation of hard- pan in sub soil and also reduces soil erosion.

9. Some crop plants are found to produce phytoalexins when they get infected by diseases. Repeated cultivation of such crops results in harmful effects over crop plants and lower crop yield is obtained. E.g. crop- phytolalexins produced by diseased plants.Groundnut -Resvertrol, Soybean-Glyceollins.
10. The family needs of feed, food, fuel, fiber, spices, sugar etc. are fulfilled and also fulfill needs of livestock.
11. Advantages of raising short duration crops (catch crop/ vegetables) when long season crops cannot be raised due to some reasons.

Factors to be considered while planning a crop rotation :

Growing different crop is very beneficial, but sometimes the desired crops cannot be grown because of certain governing factors (soil and climate), irrigation, availability bullock and other powers, market facilities and type of farming.

The Factors are as below :

1. Net profit per hectare.
2. Growth habit and nutrient requirement of different crops.
3. Soil type and slope.
4. Infestation of weeds, pests and diseases.
5. Irrigation facilities.
6. Climatic conditions.
7. Land, labour, power and other resources.
8. Food habit and requirements.
9. Market facilities.

Principles, based on which the crops should be selected for crop rotation :

1. The crops with taproot should be followed by those, which have a fibrous root system. This helps in proper and uniform

use of nutrients from the soil and root do not compliant with each other for uptake of nutrients.

2. A shallow rooted grain crop, deep rooted cash crop and restorative crop (legume crop) should be included in the rotation for providing food, fodder, cash and maintaining the fertility and productivity of soil.
3. The leguminous crops should be grown after non-leguminous crops because leguminous fix atmospheric "N" into soil and more organic matter to soil, while non- leguminous are fertility crops. Apart from this, legumes need more phosphate and less nitrogen while non- legumes need more of nitrogen and relatively low phosphorus. So nutrient requirements of these crops are different and such combination helps farmers in reducing cost of cultivation.
4. Selection of the crops should be based on soil, climate season and market demand.
5. More exhaustive crops should be followed by less exhaustive crops because crops like potato, sugarcane, maize, etc. need more inputs such as better tillage, more fertilizer higher number of irrigations, more insecticides, better care than crops like oil seeds, pulses, etc. which need little less care or little less inputs.
6. As per availability of irrigation water, two or three crops are taken in a year on same land under irrigated conditions. However a dry crop should be included in the rotation to avoid damage to the soil due to continuous irrigation.
7. In case of rain fed farming (assured rainfall) on moisture retentive soils after harvest of Kharif crop some minor crop requiring less moisture like pulses or cereals may be grown. E.g. Rice (Kharif) – Gram/ Wal (Rabi), Green gram or black gram- Rabi sorghum, sorghum, sorghum –gram.

8. The selection of crops should be problem based e.g. on sloppy lands which are prone to soil erosion, an alternate cropping of erosion promoting (erect growing crops like millet etc) and erosion resisting crops like legumes, should be adopted. Selection of crops should suit the farmer's financial conditions.
9. Both wide spaced crop and thickly planted crops should be included in rotation for control of weeds. E.g. wide spaced crops like tobacco controls weeds due to frequent inter culturing ands dense (thick) forage or legume crops controls weeds and soil erosion e.g. soybean.
10. Crops with different botanical relationship should be altered for control of weeds, pests and diseases, e.g. If crops of Graminae are grown gramminaceous crops.
11. Effect of previous crop on succeeding crop should be considered for obtaining maximum yield and harvest quality of produce.
12. Enough elasticity may be kept in rotation so that if pest or diseases destroys a crop, another crop can be substituted
13. Fertile and well-drained land should be utilized for important good rotation, less fertile land for soil improving crops (legumes) and salt tolerant crops on acidic, saline or alkali soils.
14. The ideal crop rotation should be built up around a hub crop for which the greatest comparative advantages exist. E.g. In areas of dairy industry oil seeds like groundnut or pulses will supply cattle feed (oil cakes and roughages) or in irrigated areas near cities, growing of vegetables or floriculture will be profitable.
15. Selection of crops should be demand based, i.e. the crops, which are needed by the people or area. So that produce can

be sold at a higher price. The area devoted to each crop should be constant from year to year.

Efficient cropping systems :

Efficient cropping systems for a particular farm depend on farm resources, farm enterprise and farm technology. The farm resources Include land, labour, water, capital and infrastructure. When land is limited, intensive cropping is adopted to fully utilize available water and labour. When sufficient and cheap labour is available, vegetable crops are also included in the cropping system as they require more labour. Capital intensive crops like sugarcane, banana, turmeric etc., find a place in the cropping system when capital is not a constraint. In low rainfall regions (<750 mm/annum) monocropping is followed and when rainfall is more than 750 mm, intercropping is practised. With sufficient irrigation water, triple and quadruple cropping is adopted when other climatic factors are not limiting. Farm enterprises like dairying, poultry etc., also influence the type of cropping system. When the farm enterprise includes dairy, the cropping system should contain fodder crops as components. Change in cropping system takes place with the development of technology. The feasibility of growing four crop sequence in Gangetic alluvial plains gave impetus to multiple cropping.

Interactions in different crops in cropping system :

When crops are grown in association as in intercropping, there is interaction between different component crops. This interaction may be competitive or non-competitive or complementary. When crops are grown in sequence, residual effect of the preceding crop influences the succeeding crop. This may be harmful or helpful. The toxic chemicals (allelopathic chemicals) left in the soil by the roots of sunflower crop inhibit germination of the succeeding crop. The stubbles of sorghum with high C : N ratio cause immobilization of nitrogen, thus causing nitrogen deficiency in early stages of the succeeding crop. The roots of legume crops and their residues add nitrogen to the soil.

The term interference is used to describe the effect that the presence of one plant has on the environment of another. Interference can be divided into two : 1.removal reactions of one plant on its environment and 2.additive reactions when something is added. When some factor is removed from the environment, the resulting response of neighbouring species can be negative, positive or neutral. Competition among plants is one example for removal interactions. Where some factor is added to the environment, the response of neighbouring species can be negative, positive or neutral. Some such additive interactions are allelopathy and symbiosis.

Interactions in Intercropping :

Plant requires growth factors such as solar radiation, water, nutrients and carbon dioxide for their growth. In inter or mixed cropping different kinds of plants compete with one another for the limited growth factors.

1. Solar Radiation :

The taller crop in the intercropping systems intercepts most of the solar radiation while shorter component suffers. In some intercropping systems, solar radiation is utilized efficiently by both crops. In groundnut+ redgram intercropping system, light interception is prolonged as redgram starts growing after the harvest of groundnut. If the component crops have different growth durations, the peak demand for light occurs at different times. In maize+ greengram intercropping system, greengram flowers in 35 days after sowing and is harvested 65 days after sowing. Peak light demand for maize occurs at 60 days after sowing when greengrarn is ready for harvest. In such intercrops, there is less competition among component crops and higher solar radiation is intercepted in intercropping systems than in pure stands.

2. Water and Nutrients :

Competition for water and nutrients results in two main types of effects on the less successful or suppressed component. First, the roots of dominated crop may grow less on the sides of aggressive component. The suppressed components adapt to such conditions by increased capacity for uptake. Also, if one part of the root system is on the depleted side, the remaining part shows compensatory activity and vigour. Secondly, plants affected by competition for soil factors are likely to have increased root/shoot ratio.

3. Allelopathy :

Allelopathy is any direct or indirect harmful effect that one plant has on another through the release of chemical substances or toxins into the root environment. Some crops may be unsuitable to be grown as intercrops because they may produce and excrete toxins into the soil which are harmful to other components.

4. Annidation :

Annidation refers to complementary interaction which occurs both in space and time.

Annidation in Space :

The canopies of component crops may occupy different vertical layers with taller component tolerant to strong light and high evaporative demand and shorter component favouring shade and high relative humidity. Thus, one component crop helps the other. Multistoried cropping in coconut gardens, planting of shade trees in coffee, tea and cocoa plantations use this principle. Similarly, root systems of component crops exploit nutrients from different layers thus utilising the resources efficiently. Generally, one component with shallow root system and another with deep root system are selected for intercropping as in setaria (shallow)+ redgram (deep) intercropping system.

Annidation in Time :

When two crops of widely varying duration are planted, their peak demands for light and nutrients are likely to occur at different periods, thus reducing competition. When the early maturing crop is harvested, conditions become favourable for the late maturing crop. This has been observed to occur in sorghum+ redgram, groundnut+ redgram and maize+ greengram intercropping systems.

5. Other Complementary Effects :

In an intercropping system, involving a legume and a non-legume, part of the nitrogen fixed in the root nodule of the legume may become available to the non-legume component. The presence of rhizosphere microflora and mycorrhiza on one species may lead to mobilization and greater availability of nutrients not only to the species concerned, but also to the associated species. Another example is the provision of physical support by one species to the other in intercropping system. Erect crop plants may improve the yield of a climber as in the case of coconut+ pepper, maize+ beans. The taller component acts as wind barrier protecting the short crop as in maize+ groundnut, onion+ castor and turmeric+ castor.

Interactions in Sequence Cropping :

Competition for light, water and nutrients as in mixed crop communities does not occur when sole crops are grown in sequence. It occurs only in relay cropping where there is a short span of overlapping between two crops in a sequence and the relay crop experiences the shortage of light. The important purpose in sequential cropping is to increase the use of solar radiation. It is achieved by longer field duration and rapid ground coverage. Crops are raised one after another to keep the land occupied by the crop for longer period. If the crop development is slow, much of the solar radiation reaches the ground, favoring weed growth and increasing evaporation losses from the soil surface.

In sequential cropping, the preceding crop has considerable influence on the succeeding crop mainly due to changes in soil conditions, presence of allelopathic chemicals, shift in weeds, and carry over effects of fertilizers, pests and diseases. Field preparation is difficult after rice crop since soil structure is destroyed due to puddling. Crops like sorghum and sunflower leave toxic chemicals in the soil which do not allow germination of subsequent crops. The previous leguminous crop leaves considerable amount of nitrogen for the succeeding crop. Phosphorous applied to the previous crop is available for the succeeding crop. Weed number and species differ in the succeeding crop due to the effect of the previous crop. Wheat crop that follows rice suffers from high density of weed Phalaris minor. The pests and diseases in crop stubbles and other residues of the previous crop may infect the subsequent crop.

CHAPTER - 10

Indices for evaluation of cropping systems

Several crops are involved in cropping system, hence it is not logical to compare total yield of different crops in one system with the other. Several indices are developed to evaluate cropping systems.

The crop combinations possibilities are many and also animal and crop combinations are sizeable in number. For each type, a suitable type of methodology may be be made useful to test the efficiency of the system. Some of the available indices collected from reading materials and books are presented for the sake of learning.

The influencing physical factors on the systems production *viz.*, solar energy, nutrients water carbon-di-oxide are already discussed and they form the basis for the evolving many evaluation methods. The principle of biological interactions with environment and among themselves forms other methods of evaluation. The physical environmental Components are combined in most of the evaluation methods worked out.

1. Multiple Cropping Index (MCI)

MCI is the sum of area planted to different crops and harvested in a single year divided by the total cultivated area expressed as percentage.

$$MCI = \frac{\sum_{i=1}^{n} ai}{A} \times 100$$

Where n is total number of crops; ai, area under i[th] crop planted and harvested within one year and A is total land area available for cultivation. In old literature, it is referred to as cropping intensity.

2. Cropping Intensity Index (CII)

CII assesses farmers actual landuse in area and time relationships for each crop or group of crops compared to the total available land area and time including the land temporarily available for production.

$$CII = \frac{\sum_{i=1}^{NC} ai\ ti}{A_0 T + \sum_{i=1}^{m} Aj\ Tj}$$

Where NC is total number of crops grown by a farmer during the time period i (usually one year); ai, area occupied by i^{th} crop, ti, duration of crop; A_0, farmer's cultivated land area; m, total number of fields temporarily available; Aj, land area of the j^{th} field and Tj is time period Aj available for cultivation.

In simpler terms, CII indicates the number of times a field is grown with crops in a year. It is calculated by dividing gross cropped area with net area available in the farm, region or country.

$$CII = \frac{\text{Gross cropped area}}{\text{Net area}} \times 100$$

Gross cropped area is the area sown under different crops in different seasons in an year on the available land.

3. Cropping intensity/ Intensity of cropping (CI) :

$$CI = \frac{\text{Total cropping area}}{\text{Net cultivated area}} \times 100$$

4. Rotational Intensity (RI) :

$$RI = \frac{\text{No. of crops grown in a field}}{\text{Years of rotation}} \times 100$$

5. Cultivated Land Utilization Index (CLUI)

CLUI is calculated by summing the products of land area planted to each crop and actual duration of the crop which is divided by the product of total cultivated land area and number of days in an year.

$$CLUI = \frac{\sum_{i=1}^{n} ai\ di}{A \times 365}$$

Where di is days the i^{th} crop occupied.

It is calculated by summing the products of land area planted to each crop, multiplied by the actual duration of that crop and divided by the total cultivated land area times 365 days.

i = 1, 2, 3 crops 1

n = total no. crops

a = area occupied by i^{th} crop

d = days that i^{th} crop occupied ai

A = total cultivated and area available during 365 days period.

6. Area time equivalent ratio (ATER) :

It takes in to account the duration of crops and permits an evaluation of crops on yield per day basis. It is a modification of LER.

$$ATER = \frac{LA \times DA + LB \times DB}{T}$$

Where, LA and LB are relative yields or partial LERs of component crops A and B, DA and DB are duration of crops A and B and T total duration of the intercropping system.

7. Crop Equivalent Yields

The yields of different intercrops are converted into equivalent yield of any one crop based on price of the produce. The crop equivalent yield (CEY) is calculated as follows :

$$CEY = \sum_{i=1}^{n} (yi.ei)$$

Where Yi is yield of ith component and ei is equivalent factor of i^{th} component or price of ith crop.

8. Land Equivalent Ratio

Land equivalent ratio (LER) is the relative land area under sole crops that is required to produce the yields achieved in intercropping. LER can be mathematically represented as follows :

$$LER = \sum_{i=1}^{m} \frac{Yi}{Yij}$$

Where Yi is the yield of i^{th} component from a unit area grown as intercrop and Yij is the yield of i^{th} component grown as sole crop over the same area. In brief, LER is the summation of ratios of yields of intercrop to the yield of sole crop.

9. Relative Yield Total (RYT)

In pastures, different species of plants are grown for grazing in different proportions. The yields of these crops are higher when they are grown as sole crops with 100 per cent population compared to their yield in pastures with reduced population. To accommodate more number of crops in pastures, certain amount of population of intercrops are reduced. It is necessary to know which crop combination gives higher forage yield. The yield advantage is, therefore, measured not only based on unit area, but also based on unit population which is estimated by relative yield total. This is mainly used for replacement series of experiments. It is mathematically expressed as :

$$RYT = \frac{Yaa + Ybb}{Yab + Yba}$$

Where Yaa is yield of component 'a'as sole crop, Ybb Yield of component 'b' as sole crop; Yab yield of component 'a' as inter crop in 'b' and Yba is yield of component 'b' as intercrop in 'a'.

Relative crowding coefficient, competition ratio can also be used systems.

10. Staple land Equivalent Ratio (SLER) :

In situations, where the primary objective is to produce fixed yield of one component (Staple) and some yield of other crop, the concept of SLER is proposed.

11. Relative Crowding coefficient :

The other index used is relative crowding coefficient, which can be defined in terms of LER component as

$$\frac{LA}{1 - LA} \times \frac{LB}{1 - LB}$$

The two main indices of dominance are the aggressivity and competition index. Aggressivity gives a simple measure of how much a relative yield increase in species A is greater than that species B. it is an index of dominance.

12. Competition index (CI) :

It is a measure to find out the yield of various crops when grown together as well as separately. It indicates the yield per plant of different crops in mixture and their respective pure stand on a unit area basis.

In the yield of any crop grown together is less than its respective yield in pure stand then it is harmful association, but an increased yield means positive effect.

13. Competition ratio (CR) :

It is simply the ratio of individual LERs of the two component crops, but correcting for the proportion in which they were initially sown.

14. Competition Coefficient (CC) :

Ratio of the Relative crowding coefficient of any given species in the mixture.

15. Sustainable Yield Index (SYI) :

The increase of yield or maintaining the yield over a period of time. Which is being calculated by-

Sustainability = Maximum Yield obtained- Standard Deviation/ Maximum yield obtained during the period of cultivation.

The index value more than 0.75 is considered to be highly sustainable

CHAPTER- 11

Sustainable Agriculture

The world's population is expected to rise dramatically over the next 40 years, from 6.9 billion in 2013 to 9.2 billion by 2050. At the same time, economic development will lead to an increase in demand for meat, dairy, vegetables and fruit. To feed the world and to feed it well, global food production will need to double by 2050. The problem, however, is that half of the habitable land on Earth is already used for farming. As resources are limited, the challenge is to achieve global food security while having a positive impact on the environment and society. Sustainable agricultural practices provide the solution.

Modern agriculture begins on the research station, where researchers have access to all i.e., necessary inputs of fertilizers, pesticides and labour at all the appropriate times. But when the package is extended to farmers, even the best performing farms cannot match the yields the researchers get. For high productivity per hectare, farmers, need access to the whole package – modern seeds, water, labour, capital or credit, fertilizers and pesticides. Many poorer farming households simply cannot adopt the whole package. If one element is missing, the seed delivery system fails or the fertilizer arrives late, or there is insufficient irrigation water, then yields may not be much better than those for traditional varieties.

Even if farmers want to use external resources, very often delivery systems are unable to supply them on time. Where production has been improved through these modern technologies, all too often there have been adverse environmental and social impacts in both the advanced and developing countries including India.

Adverse effects of modern high- input agriculture :

1. Overuse of natural resources, causing depletion of groundwater, and loss of forests, wild habitats, and of their capacity to absorb water, causing waterlogging and increased salinity.
2. Contamination of the atmosphere by ammonia, nitrous oxide, methane and the products of burning, which play a role in ozone depletion, global warming and atmospheric pollution.
3. Contamination of food and fodder by residues of pesticides, nitrates and antibiotics.
4. Contamination of water by pesticides, nitrates, soil and livestock water, causing harm to wildlife, disruption of ecosystems and possible health problems in drinking water.
5. Build up of resistance to pesticides in pests and diseases including herbicide resistance in weeds
6. Damage of farm and natural resources by pesticides, causing harm to farm workers and public, disruption of ecosystems and harm to wildlife.
7. Erosion of genetic diversity – the tendency in agriculture to standardize and specialize by focusing on modern varieties, causing the displacement of traditional varieties and breeds.
8. New health hazards for workers in the agrochemical and food processing industries

In the study and implementation of a broad concept of sustainable agriculture following main points should be take into consideration-

1. The interrelatedness of all the farming systems including the farmer and the family.
2. The importance of many biological balances in the system.
3. The need to maximize desired biological relationships in the system and minimize the use of materials and practices that disrupt these relations.

Definition of Sustainable Agriculture

1. The agricultural production and management system in which, the food, fodder, fiber and fuel needs of present generation are fulfilled without damaging or deteriorating the resources to fulfill these needs of future generation.
2. Sustainable Agriculture refers to a range of strategies for addressing many problems that effect agriculture. Such problems include loss of soil productivity from excessive soil erosion and associated plant nutrient losses, surface and ground water pollution from pesticides, fertilizers and sediments, impending shortages of non- renewable resources, and low farm income from depressed commodity prices and high production costs. Furthermore, "Sustainable" implies a time dimension and the capacity of a farming system to endure indefinitely. (Lockertz, 1988)
3. The successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the Natural resource- base and avoiding environmental degradation. (TAC-CGIAR, 1988)
4. A sustainable Agriculture is a system of agriculture that is committed to maintain and preserve the agriculture base of soil, water , and atmosphere ensuring future generations the capacity to feed themselves with an adequate supply of safe and wholesome food. (Gracet, 1990)

5. A Sustainable Agriculture system is one that can indefinitely meet demands for food and fiber at socially acceptable, economic and environment cost (Crosson, 1992)

6. Sustainable Agriculture refers to an agricultural production and distribution system that-

   a. Achieves the integration of natural biological cycles and controls

   b. Protects and renews soil fertility and the natural resource base

   c. Reduces the use of nonrenewable resources and purchased (external or off-farm) production inputs

   d. Optimizes the management and use of on- farm inputs

   e. Provides on adequate and dependable farm income

   f. Promotes opportunity in family farming and farm communities, and

   g. Minimizes adverse impacts on health, safety, wildlife, water quality and the environment

Current concept of sustainable agriculture

Sustainable agriculture has environmental, social and economic dimensions – and all three must be considered together. Focusing on one or two in isolation will not give the desired results. Protecting and improving the natural environment are fundamental, and issues like climate change, energy, water scarcity, biodiversity and soil degradation need to be addressed. The social dimension covers labor rights and the health of communities, including access to and affordability of food, labor rights and community health. Food quality, safety and animal welfare are also important social aspects. On the economic side, sustainable agriculture is productive, efficient and competitive. The benefits should be seen in farm profitability, in thriving local economies, and throughout the whole value chain.

The current global concept of sustainable agriculture includes following contents :

1. Sustainable agriculture in the sense of Agriculture as Industry :

The food industry needs long-term, increased supplies of quality raw materials to cater to growing demand, but factors such as unusual weather caused by climate change and water scarcity are making production and prices more volatile. Sustainable agricultural practices and programs can help businesses ensure a reliable supply of food and open up new opportunities at the same time – such as enhancing brands and meeting new market demands. Food companies that embark on this challenge are the ones attracting the best and brightest employees. As awareness is growing amongst business operators, sustainable sourcing has become a point of differentiation in the marketplace. Moreover, the consumers they serve are increasingly concerned about where their food comes from and pay great attention to whether it is produced in a responsible way, from farm to fork.

Looking at our food production system, the biggest potential for impact lies in influencing primary production. Enhancement of sustainable sourcing and sustainable agriculture are key opportunities when this system is challenged. This understanding has a place at the top of the corporate agenda.

2. Sustainable agriculture in the sense of Water scarcity :

Water is one of the world's most important natural resources, and is central to nearly every business activity. However, a substantial increase in consumption by both the agricultural and industrial sectors raises concern on the future availability of water. Water scarcity has grave implications for agriculture, as almost 70%

of the world's surface water supplies are used for farming. It is therefore essential to protect this precious resource by implementing efficient water management techniques and sustainable practices, which can include efficient irrigation systems, water harvesting, and better water treatment and waste control.

3. Sustainable agriculture in the sense of Climate change :

Climate change, or global warming, refers to the increase in temperatures over the last 100 years due to greenhouse gas emissions from human activities, CO2, methane and nitrous oxide, as well as others. Climate change upsets the balance of natural systems. For instance, higher temperatures cause sea levels to rise, and unpredictable weather conditions upset patterns of precipitation. The effects for agriculture are serious. Crops are exposed to quite different conditions from those that suit them best, and productivity can be gravely affected. Although changes in some places can be favorable for production, in general climate change brings more risks for farmers, who have to adapt their methods to new conditions. The supply of raw materials for food businesses can be disrupted, and the quality and price adversely affected. Biodiversity is affected by changing climate and in turn it affects crop health and therefore supply. When biodiversity is compromised species die out or are exposed to new pests. Climate change interlinks issues such as water availability and biodiversity.

4. Sustainable agriculture in the sense of Land use :

The availability of land and fertile soil is essential for healthy crops and livestock. Fertile soil also promotes biodiversity, efficient use of water and filtering, and avoids run-off of nutrients. It acts as a carbon sink, countering the forces of climate change. Two billion hectares of land worldwide– twice the size of China – are seriously degraded, some irreversibly. Inadequate agricultural practices, such as the improper use of fertilizers and pesticides, lead to soil pollution, salinisation and loss of arable land. Forty percent of all arable land already suffers from some level of degradation. Farmers who work this degraded land face decreasing yields, resulting in lower income. It is therefore vital for them to adopt sustainable land use practices to keep soil healthy. This is also in the interest of companies, as fertile land is essential for securing their supply of raw materials.

5. Sustainable agriculture in the sense of Crop protection :

Protecting crops from pests, weeds and disease is an essential part of everyday farming activities, even more so in the context of rising food prices, population growth and concerns over global food security. Pest management is essential for preserving the abundance and diversity of native species and for ensuring the quality and sustainability of agricultural yields. Conventionally, pesticides and other chemical agents are used for crop protection in the agricultural sector. Different schemes for insect control need to be explored based on the characteristics of the production site. In an effort to deal with the pest pressure and promote biodiversity preservation, farmers and businesses have developed programs that not only based on the responsible use of agrochemicals but also on Integrated Pest Management strategies, such as pest monitoring and biological control.

6. Sustainable agriculture in the sense of Biodiversity :

Biodiversity refers to the wide variety of flora and fauna found in nature (wild plants, animals, insects and micro-organisms). Biodiversity also supports a number of natural ecosystem processes and services. Some ecosystem services that benefit society are air quality improvement, climate mitigation, water purification, disease control, biological pest control, pollination and prevention of erosion. Climate change, population growth and human activities are causing loss of biodiversity globally. Converting land use and deforestation can displace species from their natural habitat, causing the resulting damaged ecosystems to struggle to sustain life. For these reasons the protection of biodiversity has become a major concern in agricultural practices. Businesses are increasingly exploring ways to be productive while maintaining and improving biodiversity as they become aware that the implications of biodiversity loss extend beyond raw material availability, quality and price.

7. Sustainable agriculture in the sense of Economic aspect :

Agriculture plays a fundamental role in the economic growth and the development prospects of a vast majority of developing countries. Up to 70% of their populations live in rural settings and rely on farming for their livelihoods. Therefore, when businesses source products from these countries, they can contribute to the wellbeing of millions of rural laborers and small farmers. However, this requires that they understand the dynamics of their supply chains and the consequences of their procurement policies. To do so, buyers can benefit from partnering with researchers and NGOs to analyze impacts and from building relationships with key stakeholders, thereby ensuring that communities flourish and farmers have the capacity to supply them in the long-term.

8. Sustainable agriculture in the sense of Social aspect :

Agriculture is the largest industry on the planet which employs over one billion people worldwide. Working conditions and community health issues vary greatly according to region and continent. In developing countries, where almost three-quarters of the population relies on farming to make a living, businesses have an opportunity and a responsibility to contribute positively to the livelihood of the communities who help to produce their products. This means ensuring that farmers receive fair returns, and that good labor conditions prevail throughout the supply chain. In addition, businesses can facilitate access to education, training and health care for laborers and their families. By developing relationships throughout the supply chain, companies can help communities to prosper, and subsequently to continue producing in the long run.

9. Sustainable agriculture in the sense of Food quality and safety :

Consumers are exacting about food standards. Benefits of food such as convenience, taste, nutrition, safety, and cost are considered and trade-offs can be made. Taste can be chosen over nutrition or convenience over cost, but when safety of the food is in question, the decisions are usually made more carefully. Maintaining a safe food supply is a goal of the majority of food producers, processors, and distributors. This is achieved through the strict application of food safety standards that regulate production, handling, preparation, and storage of food in ways that prevent food borne illness. But sometimes special care must be taken that food safety standards don't result in unintended environmental or social impacts. Protection of vegetable crops from pathogens, for example, can be done while also making sure that biodiversity thrives in the landscape. Similarly, smaller suppliers can be assisted to meet rigorous standards through better functioning credit and extension systems.

10. Sustainable agriculture in the sense of Animal welfare :

Livestock plays a vital role in meeting both productivity and sustainability objectives, as it is a central element of farming. Today, animal welfare has become a major source of public concern, and consumer demand for "animal friendly" products is steadily increasing. As a result, industrialized farming has had to make the shift from focusing mainly on competition and pricing, to taking into account the welfare of animals. Indeed, it has become essential that livestock be bred, housed, fed and transported in the proper conditions, as bad animal farming practices are not only detrimental for animal well-being, but can also be at the root of a variety of environmental and food safety issues.

From the concept described above, few steps in adopting the sustainability in agriculture can be listed as below-

1. Reduced use of synthetic chemical inputs
2. Use of Organic wastes
3. Biological pest, disease and weed control
4. Crop- livestock diversification
5. Crop rotations
6. Soil and water conservation practices
7. Mechanical cultivation
8. Use of animal and green manures
9. Naturally occurring processes
10. Biotechnology

Goals of sustainable Agriculture

The ultimate goal of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resource base, protect the environment, and enhance health and safety, and to do so over the long-term. The means of achieving this is low input methods and skilled management, which seek to optimize the management and use of internal production inputs (i.e., on-farm resources) in ways that provide acceptable levels of sustainable crop yields and livestock production and result in economically profitable returns. This approach emphasizes such cultural and management practices as crop rotations, recycling of animal manures, and conservation tillage to control soil erosion and nutrient losses and to maintain or enhance soil productivity.

A sustainable Agriculture, therefore, is any system of food or fiber production that systematically pursues the following goals :

1. A more thorough incorporation of natural processes such as nutrient cycling nitrogen fixation and pest-predator relationships into agricultural production processes.
2. A reduction in the use of those off-farm, external and non renewable inputs with the greatest potential to damage the environment or harm the health of farmers and consumers, and more targeted use of the remaining inputs used with a view to minimizing variable costs.
3. The full participation of farmers and rural people in all processes of problem analysis and technology development, adoption and extension.
4. A more equitable access to predictive resources and opportunities, and progress towards more socially just forms of Agriculture.
5. A greater productive use of the biological and genetic potential of plant and animal species.
6. A greater productive use of local knowledge and practices, including innovation in approaches not yet fully understood by scientists or widely adopted by farmers.
7. An increase in self-reliance among farmers and rural people.
8. An improvement in the match between cropping patterns and the productive potential and environmental constraints of climate and landscape to ensure long-term sustainability of current production levels.
9. Profitable and efficient production with an emphasis on integrated form management : and the conservation of soil, water, energy and biological resources.

Components of Sustainable Agriculture/ Measures for maintaining Sustainability :

There are many ways to improve the sustainability of a given farming system, and these vary from region to region, However, there are some common sets of practices among farmers trying to take a more sustainable approach, in part through greater use of on-farm or local resources each contributing in some way to long-term profitability, environmental stewardship and rural quality of life.

1. Soil conservation :

Many soil conservation methods, including contour cultivates contour bunding, graded bunding, vegetative barriers, strip cropping cover cropping, reduced tillage etc help prevent loss of soil due to wind and water erosion.

2. Watershed Management :

The important developmental activities in watershed management for drylands are soil and moisture conservation measures, land use based on land capability, wasteland management, afforestation and efficient crop production practices.

3. Crop diversity :

Growing a greater variety of crops on a farm can help reduce risks from extremes in weather, market conditions or crop pests. Increased diversity crops and other plants, such as trees and shrubs, also can contribute to soil conservation, wildlife habitat and increased populations of beneficial insects.

4. Conservation-of Genetic Resources :

Use of improved varieties over large areas result in loss of land races which have to be preserved for future use.

5. Tillage :

Tillage practices used in sustainable agriculture aim at reducing soil degradation, improving weed control and helping in timely decomposition of organic matter. A common aim is to provide optimal conditions for beneficial soil organisms, thereby enhancing organic matter decomposition and nutrient recycling. Managing the top 8 cm of soil is vital because most of the biological activity, microorganisms and organic matter is in this layer.

6. Nutrient management :

Nutrients needed for the crop are met from organic sources. For example, when rice is gown by self-reliant organic farming system, green manure crops such as sunhemp, dhaincha and pillipesara are sown as a mixture in a 1 : 1 : 1 ratio and 25 kg seed of each are sown in a hectare. The green manure crop is incorporated after 40 days and two weeks are allowed for decomposition before planting rice. Instead of top dressing of chemical fertilizers like urea, ammonium sulphate, calcium ammonium nitrate etc., biogas slurry and fresh cattle urine diluted with irrigation water are pumped to the fields. Three such irrigations are given at monthly intervals. If the crop is weak, one more irrigation is given with slurry combination. Farm grown inputs like Azolla, bluegreen algae, Azotabacter, Rhizobium and other biofertilizers are used judiciously. Crop rotation with legumes is adopted for building soil fertility.

Sustainable agriculture mainly depends on soil organic matter for nutrient supply through farmyard manure, compost and green manures. In the initial stage of conversion from chemical farming to organic farming, supplemental fertilizer application is necessary until equilibrium of nutrient cycles are established.

7. Efficient Water Management :

Water management can be subdivided into rain water management and irrigation water management. The important aspects of rain water management are water harvesting, supplemental irrigation and reduction of evapotranspiration. Irrigation water management involves scheduling irrigation at appropriate time with adequate quantity of water without causing water logging, salinity and alkalinity.

8. Integrated pest management (IPM) :

IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in way that minimizes economic, health and environmental risks.

Occurrence of insects and diseases are less in organic farming probably due to greater plant and insect diversity within the redesigned agro-ecosystem. The incidence of livestock disews is much lower than in conventional 'arming. The probable reasons include higher feed quality. In natural biological communities, a certain equilibrium between plants and animal organisms is involved. Rare, widely dispersed and abundant species exist. Natural regulation in the form of an increase in disease and enemies and also shortage of food cause decline in population. In the absence of plant protection measures, it is estimated that on an average 20 to 30 per cent of yield loss occurs. Maximal yield requires the highest degree of protection and is correspondingly mom expensive. Excessive use of chemicals not only results in waste of money and energy but also builds up resistance and resurgence in insects and pathogens. Pathogens developing resistance to the chemicals is increasingly observed with the introduction of systemic chemicals.

Integrated pest control which combines cultural and biological methods and use of resistant varieties reduce dependence on ecologically aggressive chemical pesticides. Plant derived compounds such as neem and microbial control agents such as bacteria and fungi can be used instead of harmful chemicals. Helpful insects and spiders are encouraged. If it becomes necessary to control insects by insecticides, threshold levels of insect population have to be considered before making a decision to spray. For example, brown plant hopper on rice has to be controlled only when its population is more than 20 per hill. It is now considered that chemical pesticides which have selective action and are compatible with biological control agents are important for sustainable agriculture. They will be of immense use in integrated pest management strategies. It is also considered that in the near foreseeable future, these chemicals cannot be replaced by any other single method of pest control.

9. Cover crops :

Growing plant such as sun hemp, horse gram in the off season after harvesting a grain or vegetable crop can provide several benefits, including weed suppression, erosion control, and improved soil nutrients and soil quality.

10. Rotational grazing :

New management- intensive grazing systems take animals out barn into the pasture to provide high-quality forage and reduced feed cost.

11. Crop Rotation :

The selection of optimal crop rotation is important for successful sustainable agriculture. Crop rotation is very important for soil fertility management, weed, insect and disease control. Legumes are essential in any rotation and should comprise 30 to 50 per cent of the crop land. A mixed- cropping, pasture and livestock system is desirable or even essential for the success of sustainable agriculture.

12. Water quality & water conservation :

Water conservation and protection have important part of Agricultural stewardship. Many practices have been develop conserve viz., deep ploughing, mulching, micro irrigation techniques etc., protect quality of drinking and surface water.

13. Agro forestry :

Establishment of different land utilization methods with trees and other woody perennials, viz. agri-silvicuture, sili-pastoral, agri-silvi-pasture, Agri-horticulture, horti-silvi-pastoral, alley cropping, tree farming, lay farm that help conserve, soil and water.

14. Marketing :

Farmers across the country are finding the improved marketing way to enhance profitability. Direct marketing of agricultural product from farmers to consumers is becoming much more common.

Status of sustainable Agriculture in India

The survival and well being of the nation depends on sustainable development. It is a process of social and economic betterment that satisfy needs and values of interest groups without foreclosing options. Suitable Development of India demands access to state of are 'clean' technologies and have as strategic role in increasing the capabilities of the country both the environment as well as to provide thrust towards conservation and sustainable agriculture. Current research programmes towards sustainable agriculture are as follows :

1. Resistant crop varieties to soil, climatic and biotic stresses
2. Multiple cropping system for irrigated areas and tree based farming system rainfall area.
3. Integrated nutrient management
   a. Combined use of organic and inorganic sources of nutrients
   b. Use of green manures (Sesbania, Crotalaria etc.)
   c. Inclusion of pulse crops in crop sequence
   d. Use of bio fertilizers
4. Integrated pest management
   a. Microbial control
   b. Use of botanicals
   c. Use of predators

5. Soil and water conservation
    a. Watershed management
    b. Use of organics as mulch and manure
    c. Use of bio-fencing like vettiver
6. Agroforestry systems in dry lands/ sloppy areas and erosion prone areas
7. Farm implements to save energy in agriculture
8. Use of non-conventional energy in Agriculture
9. Input use efficiency
    a. Water technology
    b. Fertilizer technology
10. Plant genetic resource collection and conservation.

CHAPTER - 12

Organic Farming

"Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic agriculture systems rely upon crop rotations, crop residues, animal manure, legumes, green manure, off-farm organic wastes, mechanical cultivation, mineral bearing rocks, and aspects of biological pest control to maintain soil productivity, tilth, to supply plant nutrients, and to control insects, weeds, and other pests"

The concept of the soil as a living system which must be treated in a way that does not restrict the activities of beneficial organisms necessary for recycling nutrients and producing humus is central to this definition.

"Organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, including bio-diversity, biological cycles and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using wherever possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system"

Scope of organic farming

Interest in organic agricultural methods is growing, especially in areas where the present modern farming system has unleashed many agro-ecological and environmental problems both on and off the farm, which threaten food security.

The organic farming may prove as a perfect solution on some of the problems in modern agriculture as follows-

a) Degradation of soil quality (structured & fertility)
b) Pollution of soil, water and food with pesticides and nitrates
c) Health effects on farmers, farm workers, farm families, rural communities (apart from concerns about the non intended effects of pesticides on human beings in general, sound use of pesticides requires a technical knowledge which is often lacking in developing countries)
d) Resistance of pests to pesticides
e) Dependence on off-farm agricultural inputs which can increase poor farmers' dependence on credit facilities (to purchase synthetic fertilizers, pesticides and seed), which may result in decreased local food security and self- reliance.

Further consumer awareness of the environmental costs of agriculture is increasing. The awareness of environmental quality and health is often promoted by environmental groups, especially in developed countries. The resulting demand for organic products creates the opportunity to sell organic products at premium prices, enabling organic farmers to continue, and often expand. Some governments have begun to recognize the possibility that it may be cheaper to support organic agriculture than to rectify problems associated with certain resource- destruction production practices. For this reason, several governments have introduced subsidies for organic agriculture. For example, in Indonesia where, after a period of subsidies on pesticides, the use of this input was prohibited while efforts were put in IPM programmes.

Principles of organic farming :

1. To produce food of high nutritional quality in sufficient quantity
2. To interact in a constructive and life enhancing way with all natural systems and cycles
3. To encourage and promote biological cycles within the farming system, involving micro-organisms, soil flora and fauna, plants and animals and careful mechanical intervention
4. To maintain and increase long-term fertility of soils
5. To promote the healthy use and proper care of water, water resources and all life therein
6. To help in the conservation of soil and water
7. To use, as far as is possible, renewable resources in locally organized agricultural systems
8. To work, as far as possible, within a closed system with regard to organic matter and nutrient elements
9. To work, as far as possible, with materials and substances which can be reused or recycled, either on the farm or elsewhere
10. To give all livestock conditions of life which allow them to perform the basic aspects of their innate behavior
11. To maintain all forms of pollution that may result from agricultural practices
12. To maintain the genetic diversity of the production system and its surroundings including the protection of wild life habitats
13. To allow everyone involved in organic production and processing a quality of life confirming to the United Nations Human Rights Charter, to cover their basic needs and obtain

an adequate return and satisfaction from their work, including a safe working environment

14. To consider the wider social and ecological impact of the farming system
15. To produce non-food products from renewable resources, which are fully degradable
16. Weed, disease and pest control relaying primarily on crop rotation, natural predators, diversity, organic manuring, resistant varieties, and limited (preferably minimal) thermal, biological and chemical intervention
17. To create harmonious balance between crop production and animal husbandry
18. To encourage organic agriculture associations to function along democratic lines and the principle of division of powers
19. To progress towards an entire production, processing and distribution chain which is both socially just and ecologically responsible.

Basic differences between Modern and Organic Farming :

Production factor	**Modern Farming**	**Organic Farming**
Productivity	High	Lower than modern farming
Sustainability	Low	High
Farming system	Simple	Complex
Bio-diversity Production orientation	Uniform Market	Subsistence/ market
Usage of external inputs	High	Low
Fertilization	Inorganic	Organic
Plant protection	Curative & inorganic	Preventive & organic
Energy balance	Negative	Positive

Components of organic farming :

Organic agriculture is comparatively free from the complex problems identified with modern agriculture. It is basically a farming system, devoid of chemical inputs, in which the biological potential of the soil and the underground water resources are conserved and protected from the natural and human induced degradation or depletion by adopting suitable cropping models including agro-forestry and methods of organic replenishment, besides natural and biological means of pest and disease management, by which both the soil life and beneficial interactions are also stimulated and sustained so that the system achieves self regulation and stability as well as capacity to produce agricultural outputs at levels which are profitable, enduring over time and consistent with the carrying capacity of the managed agro-ecosystem.

Crop production and health in organic farming systems is attained through a combination of structural factors and tactical management components to ensure products of sufficient quality and quantity for human and livestock consumption.

The components of organic farming can be explored as below-

1. Integrated nutrient management :

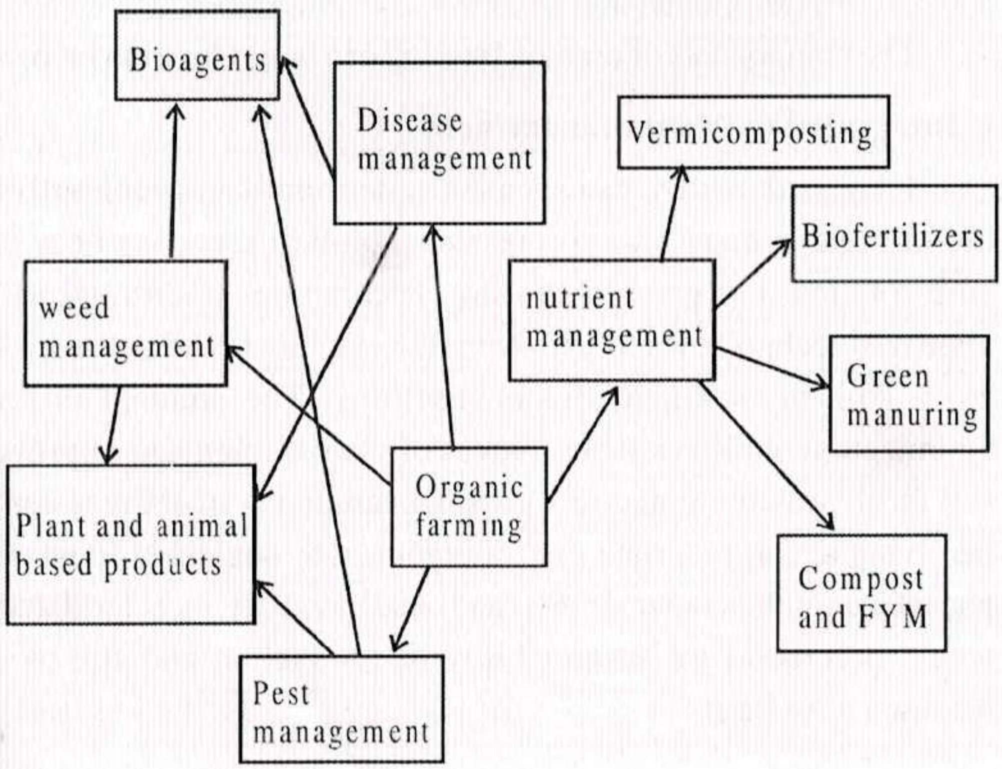
Integrated nutrient management system envisages conjunctive use of organic manures, crop residues, biofertilizers, legumes in crop rotation and green manuring. It combines traditional and improved technologies to gain from the symbiosis and synergy of crop- soil-environment bio-interactions. The concept is for optimization of all available sources of plant nutrients to improve soil fertility availing nature's gifts. Development of INM system involving and appropriate mix of organics, biological N fixation, phosphate solubilising microbes, and need based chemical fertilizers would be crucial for sustainability of production and soil as a resource base for it.

a. Bulky organic manures : In India, the estimate production of rural compost is about 226 million tons and urban compost of 6.6 million tons annually. Aggregate stability, decrease in pH, resistance to compaction, infiltration and water holding capacity. Proper methods of preparation of FYM/Compost therefore have to be popularized.

b. Recycling of organic wastes : Substantial quantities of crop residues (350 million tons) are produced in India every year. Crop residues in combination with organics have been shown to improve availability of plant nutrients, soil organic matter, aggregate stability, infiltration rate, microbial population etc.

c. Bio-fertilizers : Bio-fertilizers such as Rhizobium culture is an effective source of N supply to leguminous corps. Azotobacter and Azospirillium help in N fixation and supply to crops like rice, wheat, sorghum, maize, cotton, sugarcane, fruit corps and

Fig. 1 : Components of Organic Farming



vegetables. Phosphate solubilising bacteria viz., Bacillus aspergillus help in making available soil P to the crops and increase the solubility of indigenous sources of P like rock phosphate. Blue green algae and Azolla have shown promise in low land rice. These are renewable and environment friendly supplementary sources of nutrients and are presently being used in quantities between 8-10 tons per year. Vesicular arbuscular mycorrhiza (VAM) has beneficial effect on plant growth, particularly in P deficient soils. Improved uptake of water, production of plant hormones and microbial activity are the prime benefits of mycorrhizal inoculations.

d. Green manuring : Green manuring is a cheap alternative to the use of fertilizer N. The process also makes a positive contribution to the maintenance of soil organic matter at a satisfactory level. The stem nodulating green manure plant, *Sesbania cculeata* (Dhaincha) can fix 100-250 kg/N/ha in 45 to 55 days and has great scope in rice culture. There is also greater scope for green-leaf manuring for rice and other crops from the lopping of various multipurpose trees popularized through afforestation and agro-forestry systems.

Production and use of Vermicompost, installment of bio-gas plants, encouraging legumes in crop rotation and intercropping system and use of sewage, sludges for agriculture can also be the components of INMS.

2. Crop diversification and rotations :

Crop diversification can deliver many agronomic and ecological benefits simultaneously, while maintaining or enhancing the scale and efficiency of production. Benefits of diverse crop rotations include yield stability, reduction in disease incidence and severity, reduced pest incidence, improved weed control, reduced soil erosion, recycling of nutrient reserves, transfer or nitrogen from nitrogen fixing species, structural improvement etc. There are many different forms of crop diversification *viz.,* rotational cropping, sequential cropping, intercropping, multistoried cropping system etc., and in practice these can be combined within the farming system. Crop and variety choice and their spatial and temporal design are critical in ensuring an effective rotation. The inclusion of crops, which are able to fix atmospheric through symbiotic relationship with N-fixing bacteria that nodulate on crop roots, enables organic farming systems to be self sufficient in nitrogen.

3. Soil fertility management :

The aim of nutrient or soil fertility management within organic farming systems is to work, as far as possible, with in a closed system .Organic farming aims to manage soil fertility through use of organic manures (FYM & farm compost, vermicompost), recycling of crop residues such as straw, plant residues, grasses etc., dung and urine from domesticated animals and wastes from slaughter houses, human excreta & sewage, biomass of weeds, organic wastes from fruit and vegetable production & processing units and household wastes, sugarcane trash, oil cakes, press mud and fly ash from thermal power plant. Biological nitrogen fixation through blue green algae, azolla for rice, rhizobium for legumes, azatobactor & azospirillum for other crops, green manuring & green-leaf manuring, manure form biogas plants, legumes in crop rotations & intercropping systems.

4. Weed control :

Organic farmers often identify weeds as their key problem. Within organic systems an integrated approach to weed control using a combination of cultural and direct techniques is necessary. Appropriate soil cultivation *viz.,* deep ploughing in summer, harrowing, inter-cultivation using mechanical hoes and harrows, and the timing of field operations and good crop establishment are vital for successful control of weeds. Mulching the soil surface can physically suppress weed seedling emergence. Soil solarization, to heat field soil under plastic sheeting to temperatures high enough to kill weed seeds (>65^{0}C) can also be used for weed, control in some parts of India. Good seedbed preparation, timely sowing, line sowing, crop rotation, smoother crops & intercropping systems etc., suppress the weed growth and favour normal growth and development of crops in organic systems.

5. Natural pest and disease control :

One of the important features of organic farming is the exclusion of plant protection chemicals for pest and disease control. The system relies on the on-farm diversity, improved health of the soil and crops, protective influence of beneficial soil organisms against soil borne pathogens and use of plant based insecticides and biological control measures. The population of naturally occurring beneficial insects and other organisms which act as bio control agents multiplies making natural control of pests possible when the system is free from the indiscriminate use of chemicals. The methods of organic or natural pest and disease control includes -

a) Manipulation of crop rotations, to minimize survival of crop specific pests (in the form of, for example insect eggs, fungi) which can infest the next crop
b) Strip cropping, to moderate spreading of pests over large areas
c) Manipulation of the moisture level or pH level of the soil (in irrigated areas)
d) Manipulation of planting dates, to plant at a time most optimal for the crop, or least beneficial for the pest
e) Adjustment of seeding rate, to achieve an optimal density given the need to check weeds or avoid insects
f) Use of appropriate plant varieties for local conditions

g) Biological control methods, to encourage natural enemies of pests by providing habitat or by breeding and releasing them in areas where they are required.

   (i) *Bacillus thuringensis* against caterpillars of *Heliunthis, Earias, Spodoptera* etc

   (ii) *Pseudomonas fluoroscenes* against *Pythium spp., Rhizoctonia spp., Fusarium spp.*

   (iii) Nematodes like Green commandoes and Soil commandoes against caterpillars & grubs

   (iv) Nuclear Polyhedrosis virus (NPV) against caterpillars

   (v) *Trichoderma virdi* against many common diseases of vegetables and spices

   (vi) Weevils *Neochitina eichorniae & N. bruchi* against water hyacinth

   (vii) Beetle *Zygogramma biocolorata* against parthenium.

h) Trapping insects, possibly with the use of lures such as pheromones

i) Use of domesticated birds

j) Biological pesticides (for example neem oil, nicotine) of which the active ingredient is short-lasting, and which may be produced locally.

CHAPTER - 13

Low External Input and Sustainable Agriculture (LEISA)

The world food production tremendously increased as a result of High External Input Agricultural practices introduced by the Green Revolution. But as a result of the need for excessive capital, poor sustainability of the systems and negative impact on environment, the growers had to face many problems. Therefore development of an agricultural system using lesser external inputs, less expensive and environment friendly has become a need of many countries.

Agricultural practices with lesser inputs have been developed by integrating selected traditional basic principles with new technological knowledge. One of the most promising paradigms that have emerged for the benefit of small scale resource-poor farmers is Low External Input and Sustainable Agriculture (LEISA). It can enable such farmers to achieve higher income and attain sustainability by optimizing the use of locally available resources, thereby achieving a synergetic effect among the various components of the farming system (soil. water, animals, plants, etc.) so that they complement each other in the production of output. LEISA also helps to minimizing the use of external inputs, except where there is a serious deficiency and where the effect on the system will be to increase recycling of nutrients.

The aim is not to maximize short-term production, but to attain an adequate and sustainable level over the longer term. To achieve these goals, LEISA must tap the most viable indigenous knowledge, practices and eco-friendly approaches in a given ecological and socio cultural setting, as the experiences gained from an agro ecological system may not be appropriate for the other.

Low-External Input Sustainable Agriculture (LEISA) is a series of practices which serve to reinforce ecological principles that are in line with local ecosystems. In a simple language, LEISA can be defined as, a system of agriculture which makes optimal use of locally available natural and human resources (such as soil, water, vegetation, local plants and animals, and human labour, knowledge and skill) and which is economically feasible, ecologically sound, culturally adapted and socially just.

Practices such as recycling of plant nutrients (nitrogen and others), minimizing crop losses due to insects and pests, and securing favorable soil conditions for plant growth are just the tip of the hat. An integral component of LEISA is in ensuring that this environmental awareness remains connected to the daily lives, needs and concerns of farmers who rely on these ecosystems for their livelihoods. With regards to LEISA practices, key issues addressed to the farming communities are :

1. Maximizing the use of locally available plants and tree species
2. Reducing the use of non-renewable fuels and energy sources
3. Acknowledging the right of local communities to control, manage and benefit from natural resources
4. Ensuring that agricultural practices help to shape positive landscapes and sustained 'life support systems' for small-scale who rely on favorable environmental conditions for their survival

Principles of LEISA :

1. Creating a favorable condition for growth and sustenance of plant-by stimulating of soil micro organisms as far as possible and adding organic matter sufficiently.
2. Maintaining nutrient content at optimum level assuring the balance of nutrients in the soil by Nitrogen fixation, utilization of nutrients available in the deep soil layers, promotion of recycling process and addition of external fertilizer as and when necessary to complement deficient nutrients.
3. Controlling the micro climatic conditions to minimize loss of resources, due to sunlight, air and water. Use of biological and mechanical methods to prevent soil erosion.
4. Minimizing loss of resources caused by pests and diseases. Integration of pest control methods giving priority to natural biological control of pests by natural enemies on the principle that prevention is better than eradication.
5. Promoting biodiversity and complexity Stimulating synergetic and symbiotic conditions between plants/ plants and plants/animals.

Difference between High External Input Agriculture (HEIA)/ Conventional Agriculture and Low External Input and Sustainable Agriculture (LEISA) :

Sr. no.	High External Input Agriculture (HEIA)/ Conventional Agriculture	Low External Input and Sustainable Agriculture (LEISA)
1.	Farm practices characterized by heavy use of inorganic fertilizers and other chemical and low degree of organic recycling.	Farm management which optimizes the use of locally available natural and organic sources of nutrients and pest-disease- weed control and cyclic flow patterns to build up living soil
2.	Use of heavy- coastally machinery and modern technology for farm operations	Use of human resources and indigenous technical knowledge to maintain and increase production level
3.	Lack of conscious drive towards sustainability	Characterized by a conscious drive towardsSustainability
4.	It is only feasible for large land holder	It is feasible for both small/ marginal and large land holders
5.	Natural resources *viz.* soil, water, air are adversely affected.	Instead of adverse effects, all natural resources are conserved and improved.

The objective of LEISA system is to maintain the agricultural production at an optimum level using less external inputs in a eco-friendly environment. To achieve this objective the LEISA practices concentrated on following factors-

1. Maintaining a living soil :

Maintaining Biological characteristics of the soil. The climate, animals, plants and human being influence on the physical, chemical and biological characteristics of the soil. Adequate amount of water, air and nutrients in the soil is essential to maintain crop production at a sustainable level. Favorable soil structure is essential to retain water, nutrients and the growth of root systems of the plants. The soil temperature should exist for maintenance of living soil. It is important that soil should be free from poisonous substances. The soil contains clay, gravel, air, water, organic matter and humus. Biological activities including breeding of many micro and macro organisms taking place in the soil is an important characteristic.

a) Soil organisms : All animals and plants living in the soil are considered as soil organisms. These are- Bacteria, fungus, Algae, Protozoa, Nematodes, Weevils, Centipede, Termites, Rats, Worms, Snakes, etc.

In an extent of one hectare, top 10 cm thick layer with 1% organic matter has about 15 tons of organic matter. The weight of worms, bacteria, snails, fungus, algae and other plants and animals in this layer is about 25 tons.

b) Humus : Soil organic matter is decomposed and ultimately converted into humus by soil micro organisms. Humus acts as a pool of plant nutrients minimizing nutrients losses through infiltration. The humus acts as a binding agent of micro nutrients. Therefore a soil with adequate quantity & humus will not show any nutrient deficiency. In a sustainable agricultural system it is necessary to assure availability of adequate quantity of humus in the soil. In order to maintain productivity in a soil at optimum level the amount of nutrients removing from the soil should not exceed the in-flow of nutrients into the soil. This means that there should be mechanisms to maintain nutrient balance in the soil. The natural recycling process does it perfectly if the process is not disturbed by external agents. This process could be induced by nitrogen fixation, integrating organic manure with chemical fertilizer using appropriate crop rotation system and integrating animal husbandry into crop production. It is also important to minimize nutrient loses from the soil.

c. Soil enrichment and conservation : The forest demonstrates the natural method of receiving nutrients into the soil. The soil obtains the most of nutrients through recycling of plants and animal parts and wastes. Soil micro organisms are continuously active for decomposition of organic matter into humus. In a farm it is necessary to provide conditions to stimulate microbial activities to decompose organic matter into available forms to plants. In addition provision of partly or completely decomposed nutrients to the soil in sufficient quantities is necessary for rapid growth of the plants and to keep up soil fertility.

d. Application of green manure : In conventional agriculture, green manuring was one of the major activities carried out to enrich the soil. Particularly in paddy cultivation green manure was used to improve physical, chemical and biological properties of the soil. Besides providing nutrients green manure helps to conserve moisture. Live fence, wind blockade trees, alley crops, and cover crops can be used as sources of green manure in farms. Lopping of hedge row plants in one hectare of land provide 40-60 tons of organic manure into the soil. Thereby the soil can get about 120-160 kg of Nitrogen. Legume cover crops provide 5-30 tons of organic matter and 200 kg of Nitrogen to the soil.

e. Animal waste : From the ancient times animal wastes have been used to enrich soils. Partly or completely decomposed animal wastes are used to conserve soil moisture, to get nutrients and to stimulate microbial activities.

f. Cultivation of Nitrogen fixing plants : The legume crops grown in farms fix Nitrogen in the soil. Green gram, cowpea, soyabean, ground nut and beans are suitable legume crops for Nitrogen fixation. Glyricidia and wild sunflower are suitable legume trees for live fences and wind blockades. Legume crops in one hectare of land can fix about 40-200 kg of Nitrogen

g. Compost : The fertilizer produced from the decomposition of residues of plants and animals is called compost fertilizer. Composting is done by micro organisms in the soil. Efficiency of the system depends on the maintenance of moisture air and temperature at optimum level. Micro organisms obtain oxygen and moisture from the atmosphere and food from organic matter and release carbon dioxide and energy. The energy released in the process is used to increase the temperature of compost and to perform biological activities of micro organisms. The increased temperature affects on organic matter to undergo a series of changes to form humus. The ultimate product is a complex mixture of humus. undecomposed organic matter, dead soil organisms and living organisms. Biological restructuring of organic matter takes place in the composting process. The microorganisms can conveniently utilize the sugar in organic matter and cellulose and hemicelluloses decompose slowly through enzymatic activities.

h. Conserving soil resources : In order to ensure sustainability of living soil, attention should be paid for methodical protection of soil particles, air, moisture, organic matter, humus, micro organisms and energy. Biological and physical methods could be used to keep a living soil with optimum fertility. The methods of protecting soil fertility are explained under different headings.

i. Mulching : Mulching is the use of plant or non living materials to cover the soil surface with the objective of protecting the soil from adverse impact of rainfall and sunlight, controlling weeds or moisture loss and fertilizing the soil. Mulching is not suitable for the soils with very high moisture content. Generally for one hectare of land 3-4 tons of mulch cover is suitable.

j. Cover Crops : Cover crops are extensively used in agriculture to give protection to the soil. Selected categories of annual legume crops are more suitable for cover cropping. In addition to covering the soil, legume crops fix nitrogen in the soil. These crops also add organic matter into the soil. *Calopogonium mucunoids* and *Centrosema pubescens* are examples of legume cover crops. These crops fix Nitrogen in the soil in addition to providing organic matter. In mix cropping live mulches are often used. Legume cover crops are cultivated as runner crops with the main crop. e.g. In rubber and coconut plantation, legume cover crops are used. However the cover crops should be selected considering their less competitiveness with the main crop for moisture, space, sunlight and nutrients.

k. Alley cropping farming : Alley Cropping means growing annual or seasonal crops between rows of trees or shrubs, often leguminous. Before planting annual crops in the space between rows the vegetative parts of the trees and shrubs are pruned to use as much around annual crops and also as fodder and fuel wood. During the dry periods the trees and shrubs provide shade to annual crops and help to maintain favourable micro climate.

l. Physical and Biological methods of soil conservation : Soil erosion can be defined as the removal of soil from ground or the loss of fertility in the soil due to human activity. Sustainability of soil can be preserved by using physical and biological methods to prevent soil erosion. The wind and rains are the major factors of soil erosion. Soil structure, texture, gradient of the land and the intensity and frequency of rainfall in the area are the major factors to be considered in designing a sustainable soil conservation plan for an area.

2. Formation of biodiversity :

At the time of growing different parts of a tree, such as roots, leaves, flowers, fruits etc., are formed for fulfilling varied functions. Animals also directly or indirectly influence on activities performed by trees e.g. Bees help pollination of flowers. Each and every parts of trees carryout diverse activities and maintain inter relationships. The principle of diversity abides by plant for performing activities efficiently.

The diversity in an ecosystem depends not only on its plants and animals of different species but also on the mutual relationships among them. While each member in the system carryout more than one activity for the benefit of the system, the same activity is performed by several members in the system. Any ecosystem with higher diversity maintains a web of interactions with different organisms. If one or several members of the system fail to perform activities in a system, others continuously fill the gap and prevent break down of the process. The long term sustainability and diversity in a farm can be achieved by introducing a variety of cropping systems. Integration of crops and livestock in a farm also helps for sustenance of the system. The following methods are suggested to maintain the sustainability in a farm-

a. Multiple cropping instead of mono cropping
b. Integration of crops and livestock
c. Crop rotation
d. Establishment of forest trees.

3. Cycling and recycling process in a farm :

The natural forest ecosystem does not use external resources other than sunlight air and water. In such systems the wastage of resources is minimized and instead the resources are being used again and again. Leaves, fruits, flowers, trunks and other vegetative and reproductive parts of plants together with animal wastes and dead bodies are decomposed to form humus. Humus provides nutrients to plants. If there are no external influences this process will continue forever. In a paddy field the paddy straw can be recycled to,give nutrients. Promotion of recycling process will help to maintain the sustainability of the farming system. The relationship between inputs and outputs in a high external input agricultural system is depicted below.

4. Natural crop protection methods :

A series of actions such as reduction, prevention, extermination and controlling of pest attack can be used. The seeds and planting materials should be treated to destroy pathogens, before planting. Sometimes hot water treatment will be sufficient. Use of wood-ash and sun drying are also possible. It is advisable to use farm implements hygienically as there are possibilities of transmitting pests and diseases. Through them, infested fruits, plants leaves, ratoon crops and host plants of pests and diseases should be kept away from the farm.

a) **Cultivation of resistance varieties :** The crops resistance to pests and diseases should be selected for cultivation as far as possible. Natural pest control by predators is promoted in multiple cropping, where a variety of crops are integrated.

b) **Pest control methods :** Although there are several methods of pest control in sustainable agriculture. Priority is given to prevention of pests. Integrated pest control measures are given below-

   (i) **Biological methods :** The pest population is controlled by using natural enemies. The small scale farmers can control pests by cultivating a mixture of crops in the farm, where the pest population is balanced by natural enemies avoiding economic damage to crops.

   (ii) **Mechanical methods :** In conventional agricultural practices mechanical methods are extensively used to control the pest population hand picking trapping and removing the infested parts of crops are common mechanical methods.

(iii) **Natural pesticides :** According to the mode of action natural pesticides can be classified as follows,

Attractive : the pests are attracted by odour, colour and taste of some parts of plants. e.g. Paramours can be used to kill fruit.

Repulsive : Repulsive means keeping away the pest from reaching plants and stored products. Some plants contain substances which do not allow pests to reach and eat them. Some plants reduce the appetite of pests as soon as they start eating the plant. e.g. Neem leaves.

Some examples of natural pesticides are garlic, big onion, pepper, tobacco, neem.

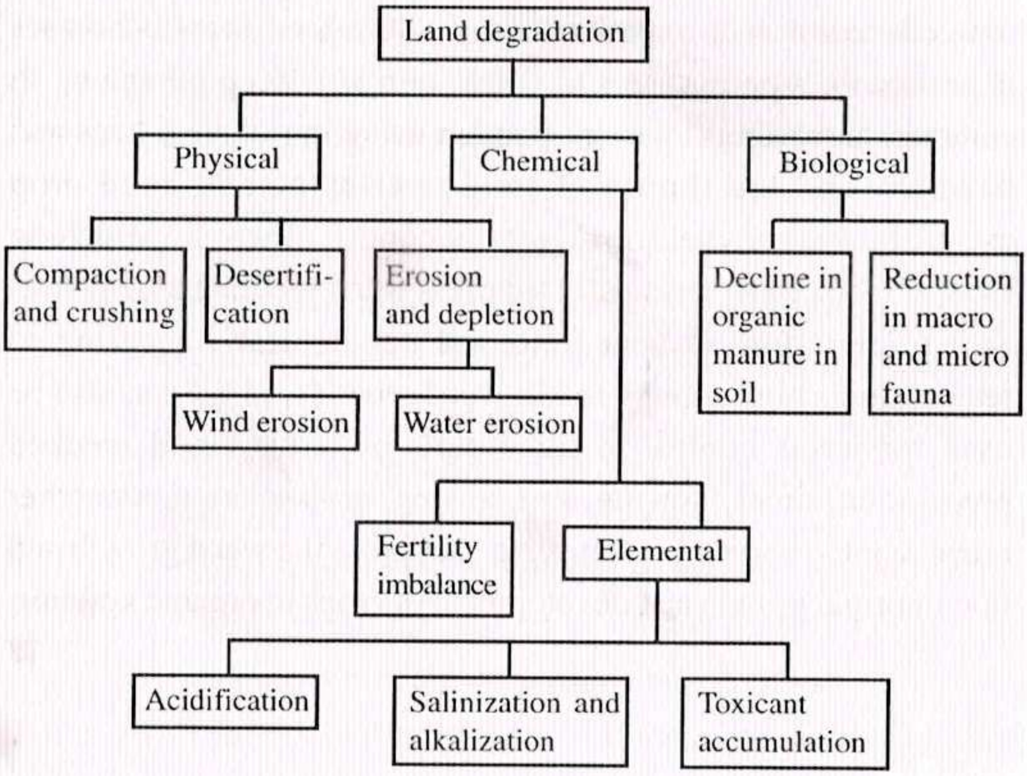
c) Weed control : Organic farmers often identify weeds as their key problem. Within organic systems an integrated approach to weed control using a combination of cultural and direct techniques is necessary. Appropriate soil cultivation *viz.,* deep ploughing in summer, harrowing, inter- cultivation using mechanical hoes and harrows, and the timing of field operations and good crop establishment are vital for successful control of weeds. Mulching the soil surface can physically suppress weed seedling emergence. Soil solarization, to heat field soil under plastic sheeting to temperatures high enough to kill weed seeds (> 65°C) can also be used for weed, control in some parts of India. Good seedbed preparation, timely sowing, line sowing, crop rotation, smoother crops & intercropping systems etc., suppress the weed growth and favor normal growth and development of crops in organic systems.

CHAPTER - 14

Land Degradation

Land degradation is a process in which the value of the biophysical environment is affected by combination of natural and human-induced processes acting upon the land. It causes a temporary or permanent decline in the productive capacity of the land.

Types of land degradation :



The causes of land degradation can be divided into natural hazards, direct causes, and indirect causes. Natural hazards are the conditions of the physical environment which lead to the existence of a high degradation hazard, for example steep slopes as a hazard for water erosion. Direct causes are unsuitable land use and inappropriate land management practices, for example the cultivation of steep slopes without measures for soil conservation. Indirect causes are the reasons why these inappropriate types of land use and management are practiced; for example, the slopes may be cultivated because the landless poor need food, and conservation measures not adopted because these farmers lack security of tenure.

The Global Assessment of the Status of Human-induced soil Degradation (GLASOD) was the first worldwide comparative analysis focusing specifically on soil degradation.

Causes of degradation as given in the GLASOD assessment

	Percentage area of degradation type caused by			
Type of degradation	Deforestation	Overgrazing	Agricultural activities	Overcutting of vegetation
Water erosion	61	67	2	44
Wind erosion	21	46	1	98
Soil fertility decline	25	0	75	0
Salinization	34	30	14	87
Waterlogging	0	0	85	33
Lowering of water table	12	22	65	34
All types of degradation	37	46	15	63

The major natural hazards in the region, environmental conditions which act as predisposing factors for land degradation, are :

For water erosion :

1. monsoonal rains of high intensity
2. steep slopes of the mountain and hill lands
3. soils with low resistance to water erosion (e.g. silty soils, vertisols).

For wind erosion :

1. semi-arid to arid climates
2. high rainfall variability, with liability to drought spells
3. soils with low resistance to wind erosion (e.g. sandy soils).
4. an open cover of natural vegetation.

For soil fertility decline :

1. strong leaching in humid climates
2. soils which are strongly acid, and/or with low natural fertility.

For water logging :

1. alluvial plains or interior basins which restrict outward drainage of groundwater.

For salinization :

1. semi-arid to arid climates with low leaching intensity
2. plains and interior basins which restrict outward drainage of groundwater
3. soils which are naturally slightly saline.

For lowering of the water table :

1. semi-arid to arid climates with low rates of groundwater recharge.

Direct causes of degradation

1. Deforestation of unsuitable land :

Deforestation is both a type of degradation as such, and also a cause of other types, principally water erosion. Deforestation in itself is not necessarily degrading without it, most productive agricultural lands (in the temperate zone as well as the tropics) would not be available. Deforestation becomes a cause of degradation first, when the land that is cleared is steeply sloping, or has shallow or easily erodible soils; and secondly, where the clearance is not followed by good management.

It is the leading cause of water erosion in steeply sloping humid environments. It is also a contributory cause of wind erosion, soil fertility decline and salinization.

2. Overcutting of vegetation :

Rural people cut natural forests, woodlands and shrublands to obtain timber, fuel wood and other forest products. Such cutting becomes unsustainable where it exceeds the rate of natural regrowth. This has happened widely in semi-arid environments, where fuelwood shortages are often severe. Impoverishment of the natural woody cover of trees and shrubs is a major factor in causing both water erosion and wind erosion. In the GLASOD assessment it is cited as a cause for 98% of the area affected by wind erosion. This assessment also cites it as a contributory cause to salinization.

3. Shifting cultivation without adequate fallow periods :

In the past, shifting cultivation was a sustainable form of land use, at a time when low population densities allowed forest fallow periods of sufficient length to restore soil properties. Population increase and enforced shortening of fallow periods has led to it becoming non-sustainable. Shifting cultivation is found in the hill areas of northeast India, where it is a cause of water erosion and soil fertility decline.

4. Overgrazing :

Overgrazing is the grazing of natural pastures at stocking intensifies above the livestock carrying capacity. It leads directly to decreases in the quantity and quality of the vegetation cover. This is a leading cause not only of wind erosion, but also of water erosion in dry lands. Both degradation of the vegetation cover and erosion lead to a decline in soil organic master and physical properties, and hence in resistance to erosion.

Intense grazing at the end of the annual dry season, and during periods of drought, does not necessarily lead to degradation; the vegetation may recover during the succeeding rains. Degradation occurs when the recovery of vegetation and soil properties during periods of normal rainfall does not reach its previous statue.

5. Non-adoption of soil-conservation management practices :

Under arable use, management practices are needed to check water erosion on all sloping lands. In dry lands, measures to check wind erosion are necessary also on lever land. Soil conserving management practices may be grouped into :

a) Biological methods : maintenance of a "round surface cover, of living plants or plant litter; vegetative barriers, including both contour hedgerows and grass strips; and windbreaks and shelterbelts.

b) Earth structures : terraces, and the various forms of bank-and ditch structures (bunds, storm drains, etc.).

c) Maintaining soil resistance to erosion : primarily, maintenance of soil organic matter and thereby aggregation and structure.

6. Improper crop management practices :

a) Improper crop rotations : As a result of population growth, land shortage and economic pressures, farmers in some areas have adopted cereal-based, intensive crop rotations, based particularly on rice and wheat, in place of the more balanced cereal-legume rotations that were formerly found. This is a contributory cause of soil fertility decline.

b) Use of agrochemical (chemical fertilizers and pesticides) : The adverse effect of use of chemical fertilizer : Plants take up nutrients from soil. Repeated crop cultivation depletes nutrients in the soil removed from it. Therefore, nutrients in soil have to be augmented periodically by applying chemical fertilizers. However, excess use of chemical fertilizers and pesticides leads to the following problems :

i) Widespread imbalance in the soil nutrients : Most of the chemical fertilizers used in modern agriculture contains macronutrients like nitrogen, phosphorus and potassium (NPK). Excessive addition of NPK to the soil however causes the plants to absorb more micronutrients from the soil. As a result soil becomes deficient in micronutrients like zinc, iron, copper etc, and the soil productivity decreases.

ii) Eutrophication of water bodies : Fertilizer which is not used by plants is washed down with rainwater and carried into water bodies, resulting in eutrophication or algal bloom leading to death of aquatic life.

iii)Health problems : About one fourth of the applied fertilizer is not used by the crop plants and is leached down into the soil and underground water aquifer. The chemical which usually leaches down is nitrate whose increased concentration in the drinking water may cause serious health problems. Excess nitrates in water is harmful especially in bottle-fed infants in whom cause the disease, methaemoglobinaemia.

The adverse affects of the use of plant protection chemicals : Toxic chemical used to kill pests of cultivated crops. Toxic chemicals like insecticides, herbicides, fungicides, rodenticides are generally used to kill insects, weeds, fungi and rodents in order to protect crop plants from their attack. These poisonous chemicals are collectively called biocides (agents that kill organism) they are not selective i.e., they not only kill the target pests but may also kill other non/not target and other useful organisms. Moreover, Biocides tend to remain active long after destroying the target organisms i.e. pests, weeds, fungi or rodents. It is persistence that makes these chemicals harmful to us.

Continued application of biocides cause various problems which are as follows :

i) They contaminate food materials and drinking water.

ii) They disrupt the balance of the natural ecosystem by killing non-target often-useful organisms.

iii) The continuous use of biocides results in a gradual increase of the immunity of the pest to these chemicals. The biocides after a period of time become ineffective against the pest leading to excessive multiplication of the pests.

iv) Most of these chemicals are persistent and not biodegradable and so they persist in the plant or animal body once they enter the food chain. Their concentration in the organisms multiplies progressively through the food chain due to biological magnification

c) Excessive irrigation : Excessive irrigation of soil may leads to water logging and accumulation of salt in the soil. Both these degrade the soil.

i) Water logging : Excessive irrigation of land without proper drainage raises the water table. This causes the soil to become drenched with water or water logged. This waterlogged soil cannot support good plant growth due to lack of air particularly oxygen in the soil, which is essential for respiration of plant roots. Water logged soils lack mechanical strength and cannot support the weight of plants which fell down and gets logged thus become submerged in the mud. This result in loss of productivity of the soil.

ii) Salt accumulation : In areas of high temperature, excessive irrigation of land usually causes the accumulation of salt in the soil. This is because water evaporates fast leaving behind traces of salt in the soil. As cycles of irrigation are repeated the left over salt accumulated and forms a thick layer of grey or white effervescence on the surface. The productivity of salt affected soil is low. Plants in saline soil are unable to absorb nutrients and so face water stress (lack of water) even when moisture is abundant in the soil.

d) Impact of high yielding plant varieties : High Yielding Varieties (HYV) have helped to increase food production but at the same time they have greatly impacted to the environment are man made varieties of agricultural plants, fodder plants, forest trees, livestock and fishes. This means that the HYV have been raised and modified by us by means various breeding techniques in order to increase productivity. The HYVs require adequate irrigation and extensive use of fertilizers, pesticides to be successful.

7. Poor planning and management of canal irrigation :

The development of salinization and waterlogging on the large-scale canal irrigation schemes of the Indo-Gangetic plains has been frequently described. Application of water in excess of natural rainfall led to a progressive rise in the water table from the 1930s onward. Where the water table has reached close to the surface, waterlogging occurs leading, through evaporation of water containing salts, to salinization. Sodification follows where sodium replaces other bases in the soil exchange complex. The problem could have been avoided, or reduced, if deep drains had been included in the initial implementation of irrigation schemes.

8. Overpumping of groundwater :

In areas of non-saline ('sweet') groundwater, the technology of tubewells has led to abstraction of water in excess of natural recharge by rainfall and river seepage. This has progressively lowered the water table.

Indirect causes of land degradation :

These are the reasons why these inappropriate types of land use and management as described under direct causes are practiced by farmers. They can be explained as follows-

1. Land shortage :

It has always been recognized that land is a finite resource, but only recently has the full impact of this fact occurred. In earlier times, food shortage or poverty could be combatted by taking new, unused, land into cultivation. Over most of South Asia, this solution is no longer available.

When combined with increases in rural population, land shortage has led to decreases in the already small areas of agricultural land per person. In India, the relative decrease in land per person over 1980-90 was 14%. There is almost no unused but usable land in South Asia. All of the best land is already taken up, and that which is not, cannot be used agriculturally on a sustainable basis.

2. Economic pressure :

Small land holdings lead to severe economic pressures on farmers, to obtain sufficient food and income to meet immediate needs. Because of such pressure in the short term, labour, land and capital resources cannot be spared to care for the land, for example green manuring or soil conservation structures. This is also the underlying reason for two other direct causes noted above, improper crop rotations and unbalanced fertilizer use.

3. Poverty :

In the developing countries such as- India, the majority of farmers remain close to, or below, the margin of poverty, defined as access to basic necessities of life. Poverty leads to land degradation, because it restricts farmer to imply the measures of land resource conservation with certain additional expenditure than the cost of regular cultivation practices.

4. Population increase :

Together with land shortage, the second basic cause of degradation is the continuing increase in rural, agricultural, population. Urban populations are increasing faster than rural. The trend towards urbanization, however, is not sufficient to reverse the key that absolute levers of rural population have increased and are increasing. The excess pressure of increasing population is given on the same and small land. It is responsible for faulty agricultural practices and overall land utilization which tends to degradation of land.

Agriculture technologies for preventing soil degradation :

1. Vegetative cover :

Vegetation acts as a protective cover to the planet earth. Deforestation and over grazing have been causing tremendous soil erosion and landslides. Only 4% of the geographical area in India is under pastures and grasslands. With the passing time the stress on vegetative cover in India is increasing with the growing demand for food, fodder, fuel and timber. Measures to conserve and to improve vegetative cover are highly essential to restore ecological balance, maintain biological diversity, conserve soil and water, and to prevent flood havoc. To increase the vegetation in the country, plantation practices such as the following are encouraged :

a) Afforestation : establishment of forest by artificial means on an area from which forest vegetation has always or long been absent.

b) Reforestation : restocking of felled or otherwise cleared woodland.

c) Social forestry : adoption of forestry practices by the society to meet its common requirements such as fuel, fodder, etc.

d) Agro forestry : adoption of suitable land use systems that maintains or increases total yield by combining food crops (annuals) with tree crops (perennials). These interventions reduce erosivity of rainfall/ runoff and erodability of soil through dissipation of rainfall energy by canopy, surface litter, obstructing overland flow, root binding and improving physico- chemical conditions, restore ecological balance and reduce the risk of environmental degradation. Tree planting to prevent wind erosion, trees should be planted in such a way so that they break the force of the wind. The trees not only cover soil from the sun, wind and water, they also help to hold the soil particles.

2. Cultivation and farming techniques

Certain cultivation and farming techniques also reduce soil erosion. These include :

a) Cross cultivation : Cultivation of land at the right angles to the direction of wind helps to reduce soil erosion by wind.

b) Ploughing style : The ploughing style substantially reduces the amount of erosion. Tilling the field at right angles to the slope called counter ploughing in soil of the land helps prevent or reduce soil erosion. The ridges that are created act like tiny dams and hold the water and helps its seepage into the soil instead of let it run down freely the slopes causing soil pollution. Contour ploughing can reduce soil erosion by up to 50%.

c) Strip Farming : This method is another method of soil erosion. This involves planting the main crops in widely spaced rows and filling in the spaces with another crop to ensure complete ground cover. The ground is completely covered so it retards water flow which thus soaks down into the soil, consequently reducing erosion problems.

d) Terracing : It is another method of reducing or preventing soil erosion on mountain slopes. In this method, terraces are created on the steep slopes. This is another way of preparing the fields for planting and preventing soil erosion. Terracing is usually done on slopes, by leveling off areas on the slope to prevent the flow of water down it. There are disadvantages to terracing however, in that the terraces themselves can be easily eroded and they generally require a lot of maintenance and repair.

e) Tillage time management : The time or season at which a field is tilled can also have a major effect on the amount of erosion that takes place during the year. If a field is ploughed in the fall, erosion can take place all winter long, however if the ground cover remains until spring, there is not as much time for the erosion to take place.

f) Zero tillage : No-till cultivation is also used as a preventive method for soil erosion. Specialized machinery are available that can loosen the soil, plant seeds and take care of weed control all at once with minimum disturbance to the soil. Since all of these aspects are taken care of at one time there is less time for erosion to occur. However there is an adverse effect due to this practice as weed and insect populations can increase since they are not continuously being removed and so can compete or destroy crops.

g) Polyvarietal cultivation : It also helps in controlling soil erosion. In this method the field is planted with several varieties of the same crop. As the harvest time vary for different varieties of the crops they are selectively harvested at different time. As the entire field is not harvested at one time and so it is not bare or exposed all at once and the land remains protected from erosion.

h) Addition of organic matter to the soil : It is also an important method for reducing soil erosion. This is achieved by ploughing in crop residues or entire the crop grown specifically for being ploughed into the ground. Microbes in the soil decompose the organic matter and produce polysaccharides which are sticky and act in gluing in the soil particles together and thus help the soil to resist erosion.

i) Organic farming or green manures : Instead of applying chemical fertilizer for supplementing the nitrogen content of soil, we can use the natural process that involves the use of nitrogen fixing bacteria in the legume root nodules. In addition to this, the use of organic forms of fertilizers such as cow dung, agricultural wastes also improves the nutrients status of soils. This may also help to reduce the excessive and prolonged use of chemical fertilizers and thus minimize their toxic effects.

j) Bio fertilizers : Micro-organisms are important constituents of fertile soils. They participate in the development of soil structure, add to the available nutritional elements and improve the physical conditions of soil. A large variety of micro-organisms are being used as biofertilisers for improving the nutritional status of crop fields.

k) Biological pest control (biological control) : The natural predators and parasites of pests play a significant role in controlling plant pests and pathogens. They are nowadays used by farmers to control or eliminate plant pests. The biological control agents of pests do not enter in the food chain or poison animals and so are not likely to harm mankind. Biological control of pests is an ecologically sound alternative to chemical pest control. At present some15,000 naturally occurring micro-organisms or microbial byproducts have been identified as potentially useful biological pesticides.

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CHAPTER- 15

Wastelands Management

The degraded land which can be brought under vegetative cover with reasonable effort, and which is currently under utilized and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes is generally referred as wasteland. Wastelands can result from inherent or imposed disabilities such as by location, environment, chemical and physical properties of the soil or financial or management constraints.

At present, approximately 68.35 million hectare area of the land is lying as wastelands in India. Out of these lands, approximately 50% lands are such non-forest lands, which can be made fertile again if treated properly. Waste lands are broadly categorized under two groups : 1.barren and uncultivable waste land and 2.cultivable wasteland. The first type includes lands which cannot be brought under cultivation economic use except at a very high cost whether they exist as isolated pockets or within cultivar holdings. They are mostly lands such as hilly slopes, rocky exposures, stony or leached or gully land sandy deserts.

The second type lands are cultivable but not cultivated for more than five years. It comprise lands available for cultivation, but not taken up for cultivation. Next to 'fallow' lands, cultivable w lands are important for agricultural purposes because they can be reclaimed through conservation practices for cultivation or grazing or agro-forestry.

Categories of wasteland in India :

Category	Area (in sq. kms.)
Snow Covered / Glacial	55788.49
Barren Rocky / Sheet Rock	64584.77
Sands-inland / coastal	50021.65
Land affected by salinity / alkalinity	20477.38
Gullied or ravinous land	20553.35
Upland with or without scrub	194014.29
Water logged & Marshy	16568.45
Steep sloping area	7656.29
Shifting cultivation land	35142.20
Mining / Industrial Wastelands	1252.13
Degraded / pastures / grazing land	25978.91
Under utilized / degraded notified forest land	140652.31
Degraded land under plantation crop	5828.09
Grand Total :	638518.31 sq.kms

Constraints of Wasteland Development or

The reasons why cultivable land remains wasteland:

1. Poor fertility of the soil due to rocky gravely, sandy, saline, alkali, water logged shallowness and eroded nature of the soil

2. Little or no irrigation potential
3. Not Suitable for cash crops that require fertile soil & continuous water supply
4. High cost of investment in soil & irrigation development (cost per acre) beyond the reach of most rural families
5. Improved technology required to make lands productive is beyond the skill levels of poor families
6. Complex organization required for land development, cultivation, production & marketing
7. Steep and undulated slopes
8. Shifting cultivation
9. Frequent droughts
10. Frequent submergence and flooding hazards
11. Lack of resources
12. Poor economic conditions of local people
13. Lack of labour during peak periods
14. Uneconomical return under cultivation
15. Certain domestic and legal difficulties

Need for development of wastelands :

India is the seventh largest and the second most populous country in the world with unique physical landscape has resulted in different types of land which are subjected to different types of land which are subjected to different types of utilization. Due to increasing pressure of population, there is an excessive demand of more land both for agricultural and non-agricultural use. This has resulted in uncontrolled exploitation of land resources resulting in vast stretches of wastelands such as degraded land, soil salinity, water logging, desertification, soil erosion etc., and also led to decrease in per capita availability of cultivable land besides ecological imbalances. Keeping this in view, National Wasteland

Development Board was established in 1985 under the Ministry of Forests and Environment mainly to tackle the problem of degradation of lands, restoration of ecology and to meet the growing demands of fuel wood and fodder at the national level. During the Seventh Five Year Plan, the strategy adopted by the National Wasteland Development Board emphasised more on tree planting activities rather than Community Participation for wasteland development, In the year 1992, the new Department under the Ministry of Rural Development (now Ministry of Rural Areas and Employment) was created and the National Wasteland Development Board was placed under it. The Board was reconstituted in August 1992 and was made responsible for mainly development of wastelands in non forest areas in totality by involving local people at every stage of development with the objective of bringing 5 million ha of land every year under fuel wood and fodder plantations. It aims at creating a scenario where the Government acts as a facilitator and the people at the grass root level become the real executioner of the programme. Major programme implemented for improving the productivity of waste & degraded lands keeping in view the poverty, backwardness, gender & equity is Integrated Wasteland Development Programme.

Regeneration of wastelands :

Regeneration of wastelands involves the following aspects :

1. Pasture development for fodder supply and erosion control
2. Tree plantation for fuel and timber purpose
3. Social forestry for labour employment
4. Silve-pastroal programme for fodder, fuel, timber purposes
5. Agri-horticulture system for income generation
6. Medicinal and Aromatic plants for revenue generation
7. Grasslands and fish farming in low lying areas

Strategy for Reclamation Planning of Wasteland :

The basic strategies that should be adopted in the reclamation of wasteland can be explained as follows-

1. New strategies should be adopted through the involvement of voluntary organization and government officials in making a pool for a joint move.
2. Incentive strategy should be carried out for increasing agricultural productivity, afforestation and greening wastelands.
3. A coordinating agency at the state/ District/ Block and village level should be established to help the people for technological causes of wastelands as well as various reclamation measures for increasing the productivity of such unutilized lands.
4. For planning and formulation of wastelands developmental scheme it is necessary to have a reliable data at macro, and micro levels. It will be a good exercise if the informations are collected at the village level with the help of revenue officials.
5. Farmers should be helped by the government officials for leasing of the land, credit, agricultural technological inputs, market information and marketing, including all the related materials regarding the wastelands reclamation.
6. Communication with the farmers must be utilized. Besides radio and T.V. local newspapers, films and audiovisuals to be used in the affected areas for encouraging and involving the farmers for the reclamation of wastelands.
7. Just like the green revolution there should be programme for greening the wastelands which should be the institutional structures of research of high quality seeds of extension

methods would be necessary to establish the reclamation of wastelands.

8. An effort should be made for the people's involvement through nurseries, sapling distribution, farm forestry, patta and tree patta system. Farmers should be encouraged for adopting all the ways and means to reclaim the wastelands.

Reclamation of wasteland :

As the concept wasteland covers wide range of subcategories, the methods of their reclamation are also varies.

1. Reclamation in Wind erosion prone area :

The Indian desert situated in the north-west states of Rajasthan, Gujarat, Haryana and Punjab. Nearly 70% of the desert region is covered by wind-worked sandy-soils, sands, loamy sand and sand dunes. The problems encountered in the area are wind erosion, deposition and movement of sand- dunes, low soil moisture storage, instability of soil structure and poor soil fertility etc. The following may be the suggested measures to overcome the problem.

1. Afforestation : plantation of windbreaks and shelter belts. The suitable plant species for this purpose are Prosopis chilensis (syn. P. juliflora), Azadirachta indica and Albizia libback. Soil removal in sheltered areas was only 3 tonnes/ha as against 72 tonnes/ha in unsheltered areas.

2. Grassland development : Grasses like Cenchrus ciliaris (Anjan grass and Lasiurus sindicus (wild peas) were found effective in arresting drifting of soil in April-June as suggesting that degraded lands in wind erosion –prone areas may be kept under grasses.

3. Strip Cropping : The field strip cropping of grain legumes or cereals in grass strips developed at the Central Arid Zone Research Institute (CAZRI) is very effective tool for controlling wind erosion.

4. Mulching: Mulching is found very effective in reducing the wind erosion.

5. Fixing of Sand dunes: Shifting of sand dunes is the problem in the desert area, for stabilization of which the CAZRI, Jodhpur suggested (i) protection against biotic interference (ii) treatment of sand by fixing mulch barriers in parallel strips or in a chess-board design, using the local shrub material, from the crest down to the heel of the dune against the direction of the wind to protect the seedlings from burial or exposure by the blowing of sand and (iii) planting suitable trees-grasses and shrubs for erecting wind breaks.

2. Reclamation in Water Erosion prone area :

It is well recognized that a large area in the country is degraded due to soil erosion by water. The causes of this erosion are mainly lack of vegetative cover, slope, nature of soil, rainfall, and its intensity, cropping system and land management. Depending upon intensity and degree of soil erosion it may be categorized into (i) sheet erosion (ii) Gully erosion and (iii) ravines. Appropriate measures based on these categories may be suggested to check runoff and soil loss. The measures include intercultural practices, bunding, terracing grassed water ways etc.

Cultural practices used for checking runoff and soil loss include planting erosion-resistant crops, like legumes and grasses, adopting suitable cropping system, management and use of mulches.

Mechanical measures involving some degree of earth movement like bunding terracing etc. are found effective in checking runoff and soil loss by increasing the time of concentration and reducing velocity of runoff. Contour cultivation and graded trenching (diversion) are also effective for erosion control.

Small gullies (up to 3 m deep and 18 m or more wide) may be reclaimed by leveling the bed and construction of diversion-cum-check bunds (1.5 m cross section) at 30-45 m. intervals and providing grass ramps and composite check dam at the end of the gully. Medium gullies (3-9 m deep and 18 m or more wide with side slope 8-15%) may be reclaimed by leveling the bed and constructing a series of composite earth and brick masonry check dams at vertical intervals of 1.2 m and terracing the side slopes. The terraced faces, outlets and earthen dams need to be stabilized by suitable grasses like *Dichanthium annualtum* and *Cynadon dactylon.*

The deep and narrow gullies are best controlled by putting them to permanent vegetation after closure to grazing. Afforestation with suitable tree species *Acacia nilotica, Azadirachta indica, Dalbergia sissoo, Tectona grandis, Eucalyptus sp.* and other suitable species is found suitable.

3. Reclamation in Landslide area :

The problem of landslides and landslips is common especially in the hilly areas posing threat to agricultural lands, highways and village habitants. The main causes for land-slides are weak geological formations, seismic disturbances, improper land use, deforestation, mining and glaciers. The Central Soil and Water Conservation Research and Training Institute, Dehradun has successfully demonstrated the control measures which include fencing to check biotic interference, diversion of water flow, construction of gabion wells and check dams, gully plugging and maintaining vegetation cover for stabilization and checking erosion.

4. Reclamation practices in Riverine Land, Coastal and High altitude sloppy lands:

The rivers carrying heavy sediment cause mendering action and bank erosion. The rivers originating from Himalayas causes greater effect. Depending on the velocity of flow, the fertile areas are eroded and large quantities of sediments are .deposited along the banks. Such riverine lands are called Khader in north India, Diara in eastern Uttar Pradesh and Char in West Bengal.

In hilly areas, during rainy season many seasonal streams (chos) carry sediment load causing sever soil erosion. They diverge in different directions from the foot of the hills forming a net work of innumerable chos, some of them taking the shape of big rivers. With slowing of runoff, the transported sediment of sand and silt are deposited converting fertile land into sandy and bouldery degraded land.

India has a long sea-coast in the states of Gujarat, Maharashtra, Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and West Bengal, Goa, Andaman & Nicobar. In total we have 5600 km long coast sea line. During the monsoon and cyclonic periods, there is blowing and shifting of sand causing damage to the standing crops in the neighbouring areas. Hence, plantation of Casurina on the sandy foreshore backed by plantation of other suitable tree species further inland can minimize this problem.

Keeping in view the environmental and ecological conditions in the region, land use planning requires proper choice of crop-forest pasture as suited to land and soil conditions. Grass-legume rotation is the best cropping system for soil conservation and providing nutritious fodder for the livestock. The over grazing pasture lands have to be restored and systematic and scientific grazing should be emphasized.

5. Reclamation in Salt-affected Soils area :

Salt affected soils may be classified into two categories : (i) saline soils (ii) alkaline soils.

a) Saline Soils : Irrigation and high rainfall without provision of. drainage leads to salinization. The main factors of salinization are high salt content in the profile or salt layer, saline ground water, high water table, and seepage from canals and ingress of sea. The reclamation measure largely includes leaching with good quality

.water and provision of drainage. So that the salts are kept well below the root zone. Leaching requirement for each area has to be worked out and provided accordingly so that the salt do not rise above the normal root zone level of the commonly cultivated crops.

b) Sodic or alkali soil : These type of soil occur in the Indo-Gangetic plain and parts of M.P. As these soils are saturated with sodium ions capable of alkaline hydrolysis (sodium-carbonate type salts), it will be necessary to replace the excess sodium in the exchange complex with calcium, gypsum, being relatively in expensive and abundanly available is the most commonly used amendment in the reclamation of sodic soils. Washing down with good quality of water is also necessary to leach down or remove the excess salt at the surface and the sodium released from the exchange complex. Drainage has to be provided to keep the salt well below the root zone. Once the soils are reclaimed, it may be preferable to take a green manure crop initially to improve the soil tilth.

c) Acidic soils: The suggested process of reclamation for highly acidic soils which having pH < 5.5 and are totally unproductive. The measures are (i) use of lime rich industrial wastes like basic slog, paper-mill sludge and cement factory waste to reduce the cost, (ii) annual application of 3 to 5 qt/ha in rows for legumes rather than 2 to 2.4 tonnes, for a crop cycle of 5 years and (iii) application of rock phosphate of proper quality as a source of phosphorus supplemented by lime for amelioration and Ca nutrition of plants.

6. Reclamation in Water logged Areas :

It is estimated that India is having approximately 6 m. ha water logged area. Water logging result in restriction of the normal circulation of air. The depth of water-table which is considered harmful depend upon crop, type of soil and quality of water. The remedial measures used are-

1. Drainage either surface or sub surface or both to remove surplus water
2. Lining of canals to prevent seepage and rise of water table.
3. Sinking tubewell and utilizing water for irrigation thereby 0lowering water table.
4. Waterlogged lands contiguous to the sea coast may be ameliorated for crop cultivation or used for fish culture.

7. Reclamation in area where Shifting Cultivation is followed:

Shifting cultivation or jhuming is a primitive form of cultivation practiced in north-eastern states of India or in regions where land is not a limiting factor. The dense forest and other vegetation on the slopping or other land is cleared and crops raised without any management. As yields decreases, new forest is cleared for the purpose, leaving the old area to vagaries of nature causing erosion of soil and rendering soils shallow, unstable and degraded.

For management of jhumed land the suitable land for intensive cultivation have to be identified. Depending upon the climatic factors, soil characteristics and associated features intensive system of land use and cropping pattern will have to be evolved for each specific site without being detrimental to environment. Careful soil and water conservation practices have to be formulated. Training of the farmers in the scientific farming systems and management of resources is necessary.

Other general methods and practices for reclamation of wasteland:

1. Developing wasteland with animal Husbandry :

It is considered that animals are a big nuisance causing serious degradation to vegetation on the one hand and man himself by over harvesting of wood for ever increasing need of fuel and industry on the other hand. The problem of soil degradation by animals may be overcome by the proper management of increasing demand of fodder by developing silvi-pastoral system and growing fodder crops on wasteland and developing pastures on marginal and degraded land. On pastures the grazing should be systematic. Since most of the wasteland is owned by small and marginal farmers so animal husbandry is the best source of alternative income for them.

2. Agro-horticultural forestry in Wasteland :

This system is the combination of food and vegetable crops with horticultural crops. This practice is noticed more common in the developing orchards where trees have not started fruiting. Most commonly legumes and oil seeds are grown in such orchards. The tall growing fruit trees are pruned in such a way to facilitate easy cultural operations and any seasonal and biennial crop like wheat, gram etc. is cropped in inter row space. These crops not only increases per unit land income but also conserve the soil by covering the floor.

3. Agro forestry

Agro-forestry is a self sustaining land management system which combines production of agricultural crops With of tree crops as also With that of the livestock simultaneously or subsequently on the same unit of land.

4. Maintenance of vegetative Cover :

Bringing the land under proper vegetation prevent most of the degradation of the land. The vegetative production may, be for various uses like for forage and fuel, sustained crop production, pasture, silvipasture and socio-economic uses.

a) Forage and fuel production : The degraded lands and wastelands are ecologically unstable and have nearly lost their top soils and have developed toxicity hindering root growth of the annual crops and trees. Under managed conditions with basic inputs, it has been found possible to grow high-yielding grasses, legumes and trees for forage and fuel purposes. The suggested species of trees, grasses and legumes are as following-

Trees : *Acacia tortilis* - Israeli babool, *A. lebbek-* Lebbek tree (siris), *Herdwzckza binata* – Anjan, *Leucaena leucocaphale* – Subabool, *Dalbergza sissoo* – Shisham, *D. latifolia* -Rosewood, *Azadirachta lnidca* -Neem

Grasses and legumes : *Cenchrus ciliaris* - Anjan Grass, *Stylosanthes hamata* – Stylo, *Phaseolus atropurpureaus-* Slfatro

b) Sustained Land use : Irrespective of needs like fuel, fodder, food and the condition the soil like type of slope or other degrading factor the cropping system on sustainable basis should be adopted. The suggested agronomic use depending on the slope of the land may be as follows-

1. Bare hill slopes: Grasses and trees
2. Shallow soils with slope> 6% : Grasses
3. Deep soils with slope> 6% : Cropping after bench terracing
4. Deep soils having 3-6% slope: Graded bunds and rainy season cropping
5. Deep soils 1-3% slope: Inter & double cropping
6. Deep soils 1% slope: Most suitable for cropping system depending on the resources.

c) Pasture Management : This technology is suitable for fairly leveled lands having a slope of less than 6 meter. It involves a combination of number of steps, package of practices and inputs like renovation of degraded range lands and their restructuring with mosaic flora or species or cultivars of grasses and legumes in pure and mixed stand and upgrading the soil and plant nutrients through fertilizer application. The suitable species for pasture are *Conchrus* *setigerus, C. ciliaris, Lasiurus sindicu, Panicum antidetab* etc.

d) Silvi-pasture Management : From the point of greater demand for fuel wood and small timber for human consumption and the forage and fodder for livestock and wildlife and also the land degradation that has already occurred, silvi-pastoral seems to be the best system for economic utilization of degraded lands.

Silvipastoral system of land management covers 3 major items *viz.* (a) trees valuable in themselves as conserver of land and for ameliorate of climate especially in arid and semi-arid regions besides their fuel and timber values (b) animals grazing on the pasture and feeding on the leaves of nutritious trees and shrubs and (c) occasional production of cash crops. In this system the plant components chosen are trees, shrubs, grasses and legumes.

e) Socio-economic consideration for optimum land use : For a balanced ecological system it is a well established fact that 33% or 1/3 of our total geographical area should be under forest. To a large extent farmers are choosing cash crops like wheat and paddy to get more profit but still there is a gap between the production and requirement of oilseeds pulses and forage crops.

Depending upon the suitability, and other regional factors like soil, available facilities and need, growing oilseeds, forage and pulses on partially degraded land may balance the social and economic aspects of human life. While bringing the uncultivable land under forest will definitely improve our ecology and environment.

f) Hedgerow inter cropping (alley cropping) : One of the agro-forestry technology for developing wasteland that is becoming the subject of research under a wide range of solutions is hedge row inter-cropping. It refers to a cropping system where arable crops are grown in the interspaces (or alleys) between rows of planted trees or woody shrubs, which are pruned periodically during cropping season to prevent shading and to provide green manure and mulch to the arable crop. This system is called alley cropping. In the concept of alley cropping more emphasis is made on including the trees and shrubs from legumes like *Leucaena leucocephala* and *Cajanus cajan*. Encouraging results are obtained from cultivation of leucaena with maize, cassava etc.

The hedge row intercropping system offers the advantages of incorporating a woody species within an arable farming system without impairing soil productivity and crop yields. The potential of nutrients (nitrogen) contribution by several candidate species of woody legumes suggest that a wide range of such species could be integrated into crop production systems. By adjusting the inter-row spacing of the woody species, mechanized equipment could be used, wherever it is desirable, for various field operations connected with cropping. Moreover, the trees can be cut back and kept pruned during the cropping period and leaves and twigs applied to the soil both as a mulch and a nutrient source, with the bigger branches being used as stakes or firewood.

CHAPTER - 16

Climate Change and Agriculture

Climate has obvious and direct effects on agricultural production. For the past some decades, the gaseous composition of earth's atmosphere is undergoing a significant change, largely through increased emissions from energy, industry and agriculture sectors; widespread deforestation as well as fast changes in land use and land management practices. These anthropogenic activities are resulting in an increased emission of radiatively active gases, *viz.* carbon dioxide(CO_2), methane (CH_4) and nitrous oxide (N_2O), popularly known as the 'green house gases' (GHGs. These GHGs trap the outgoing infrared radiations from the earth's surface and thus raise the temperature of the atmosphere. The global mean annual temperature at the end of the 20th century, as a result of GHG accumulation in the atmosphere, has increased by 0.4–0.7°C above that recorded at the end of the 19th century. The past 50 years have shown an increasing trend in temperature @ 0.13°C/decade, while the rise in temperature during the past one and half decades has been much higher. The Inter-Governmental Panel on Climate Change has projected the temperature increase to be between 1.1°C and 6.4°C by the end of the 21st Century. The global warming is expected to lead to other regional and global changes in the climate-related parameters such as rainfall, soil moisture, and sea level.

Snow cover is also reported to be gradually decreasing. Therefore, concerted efforts are required for mitigation and adaptation to reduce the vulnerability of agriculture to the adverse impacts of climate change and making it more resilient.

The three major GHGs are carbon dioxide, methane and nitrous oxide, besides chlorofluorocarbons.

Carbon Dioxide : The main sources of carbon dioxide emission are decay of organic matter, forest fires, eruption of volcanoes, burning of fossil fuels, deforestation and land-use changes. Agriculture is also a contributor to CO_2 emission but is not considered a major source of this important GHG. Within agriculture, soil is the main contributor with factors such as soil texture, temperature, moisture, pH, and available C and N, influencing CO_2 emission from soil. Emission of CO_2 is more from a tilled soil than from an undisturbed soil (no till). Temperature has a marked effect on CO_2 evolution from soil by influencing root and soil respiration. It may be mentioned that plants, oceans and atmospheric reactions are the major sinks of carbon dioxide.

Methane: Methane is about 25 times more effective as a heat-trapping gas than CO_2. The main sources of methane are: wetlands, organic decay, natural gas and oil extraction, biomass burning, rice cultivation, cattle and refuse landfills. The primary sources of methane from agriculture include animal digestive processes, rice cultivation and manure storage and handling. The removal in the Stratosphere and soil are the main sinks of methane. In ruminant animals, methane is produced as a by-product of the digestion of feed in the rumen under anaerobic condition. Methane is also formed in soil through the metabolic activities of a small but highly specific bacterial group called 'methanogens'. Their activity increases in the submerged, anaerobic conditions developed in the wetland rice fields, which limit the transport of oxygen into the soil, and the microbial activities render the water-saturated soil practically devoid of oxygen. The upland, aerobic soil does not produce methane. Water management, therefore, plays a major role in methane emission from soil.

Nitrous Oxide : As a greenhouse gas, nitrous oxide is 298 times more effective than CO_2. Forests, grasslands, oceans, soils, nitrogenous fertilizers, and burning of biomass and fossil fuels are the major sources of nitrous oxide, while it is removed by oxidation in the Stratosphere. Soil contributes to the largest amount of nitrous oxide emission. The major sources are soil cultivation, fertilizer and manure application, and burning of organic material and fossil fuels. From an agricultural perspective, nitrous oxide emission from soil represents a loss of soil nitrogen, reducing the nitrogen-use efficiency. Appropriate crop management practices, which lead to increased N-use efficiency, hold the key to reduce nitrous oxide emission. Site-specific nutrient management, fertilizer placement and proper type of fertilizer supply nutrients in a better accordance with plant demands, thereby reduce nitrous oxide emission.

Impacts of Climate Change on Agriculture :

Global climatic changes can affect agriculture through their direct and indirect effects on the crops, soils, livestock and pests. An increase in atmospheric carbon dioxide level will have a fertilization effect on crops with C_3 photosynthetic pathway and thus will promote their growth and productivity. The increase in temperature, depending upon the current ambient temperature, can reduce crop duration, increase crop respiration rates, alter photosynthate partitioning to economic products, affect the survival and distribution of pest populations, hasten nutrient mineralization in soils, decrease fertilizer-use efficiencies, and increase evapo-transpiration rate. Indirectly, there may be considerable effects on land use due to snow melt, availability of irrigation water, frequency and intensity of inter- and intra-seasonal droughts and floods, soil organic matter transformations, soil erosion, changes in pest profiles, decline in arable areas due to submergence of coastal lands, and availability of energy. Equally important determinants of food supply are socio-economic environment, including government policies, capital availability, prices and returns, infrastructure, land reforms, and inter and intra-national trade that might be affected by the climatic change

1. Reduction in Crop Yield :

Rise in the mean temperature above a threshold level will cause a reduction in agricultural yields. A change in the minimum temperature is more crucial than a change in the maximum temperature. Grain yield of rice, for example, declined by 10% for each 1^0C increase in the growing season minimum temperature above 32 °C.

2. Shortage of Water :

The increased temperature would result in more water shortages and the demand for irrigation water would rise. Increase in air temperature will lead to more potential evapotranspiration in the areas south of 40° N. Likewise, water shortage due to climate change would result in about 20% net decline in the rice yields in India.

3. Irregularities in Onset of Monsoon, Drought, Flood and Cyclone:

Indian agriculture is highly dependent on the onset, retreat and magnitude of monsoon precipitation, particularly in the rainfed areas of east, north-east and south India. Climate modelers and IPCC documents have projected possibilities of increasing variability in Asian Monsoon circulation in a warmer world. Despite expansion of area under irrigation, droughts, caused by inadequate and uneven distribution of rainfall, continue to be the most important climatic aberrations, which influence the agricultural production in India. The severity of a drought will be intensified in a warmer world. Intense and frequent flooding due to climate change would be a major problem in the Indian subcontinent.

4. Rise in Sea Level :

In South, South East and East Asia about 10% of the regional rice production, which is enough to feed 200 million people, is from the areas that are susceptible to 1 m rise in the sea level. Direct loss of land combined with less favorable hydraulic conditions may reduce rice yields by 4% if no adaptation measures are taken, endangering the food security of at least of 75 million people. Saltwater intrusion and soil salinization are other concerns for agricultural productivity.

5. Decline in Soil Fertility :

Soil temperature affects the rates of organic matter decomposition and release of nutrients. At high temperatures, though nutrient availability will increase in the short-term, in the long-run organic matter content will diminish, resulting in a decline in soil fertility.

6. Loss of Biodiversity :

Species of animals and plants are estimated to disappear at a rate which would be about 100-times faster than the historical record, largely as a result of human activities. A detailed assessment of the 394 species of primates from South America to Indonesia has indicated that 29% are in danger of disappearing due to hunting, habitat loss and climate change.

7. Pests, Weeds and Diseases :

As temperature increases, the insect-pests will become more abundant through a number of inter-related processes, including range extensions and physiological changes, as well as increased rates of population development, growth, migration and over-wintering. The climate change is likely to alter the balance between insect pests, their natural enemies and their hosts. The rise in temperature will favour insect development and winter survival. Rising atmospheric carbon dioxide concentrations may lead to a decline in food quality for plant-feeding insects, as a result of reduced foliar nitrogen levels. The epidemiology of plant diseases will be altered. The prediction of disease outbreaks will be more difficult in periods of rapidly changing climate and unstable weather. Environmental instability and increased incidence of extreme weather may reduce the effectiveness of pesticides on targeted pests or result in more injury to non-target organisms.

The core challenge of climate change adaptation and mitigation in agriculture is to produce- more food, more efficiently, under more volatile production conditions, and with net reductions in GHG emissions from food production and marketing. As climate change affects input availability, especially water in many places, input use efficiency must increase with these productivity demands. Carbon emission polices may simultaneously encourage or force producers to recognize GHG emissions as an important and costly "input" in production processes and open new opportunities and incentives for on farm GHG mitigation. Producers will grapple with these growing demands and shifting incentives amidst more volatile production conditions. Agricultural technologies will play a central role in enabling producers to meet these core challenges. Because agriculture is inseparably linked to climate and feedback runs in both directions, most agricultural technologies have direct or indirect climate linkages. Most new technologies change the use of farm inputs, often in ways that alter the impact of weather on production and of production on carbon emissions. While most agricultural technologies therefore have climate implications, there are a handful of current and emerging technologies with particular relevance to developing country agriculture and climate change. In this section, we describe some of these technologies in order to discuss policy and institutional considerations in the subsequent section.

Mitigation Strategies to Climate Change :

The strategies for mitigating methane emission from rice cultivation could be alteration in water management, particularly promoting mid-season aeration by short-term drainage; improving organic matter management by promoting aerobic degradation through composting or incorporating it into soil during off-season drained period; use of rice cultivars with few unproductive tillers, high root oxidative activity and high harvest index; and application of fermented manures like biogas slurry in place of unfermented farmyard manure. Methane emission from ruminants can be reduced by altering the feed composition, either to reduce the percentage which is converted into methane or to improve the milk and meat yield. The most efficient management practice to reduce nitrous oxide emission is site-specific, efficient nutrient management. The emission could also be reduced by nitrification inhibitors such as nitrapyrin and dicyandiamide(DCD). There are some plant-derived organics such as neem oil, neem cake and karanja seed extract which can also act as nitrification inhibitors. Mitigation of CO2 emission from agriculture can be achieved by increasing carbon sequestration in soil through manipulation of soil moisture and temperature, setting aside surplus agricultural land, and restoration of soil carbon on degraded lands. Soil management practices such as reduced tillage, manuring, residue incorporation, improving soil biodiversity, micro aggregation, and mulching can play important roles in sequestering carbon in soil.

Adaptation Strategies to Climate Change :

To deal with the impact of climate change, the potential adaptation strategies are: developing cultivars tolerant to heat and salinity stress and resistant to flood and drought, modifying crop management practices, improving water management, adopting new farm techniques such as resource conserving technologies (RCTs), crop diversification, improving pest management, better weather forecasting and crop insurance and harnessing the indigenous technical knowledge of farmers. Some of these strategies are discussed below.

1. Developing new traits, varieties and Crops :

Development of new crop varieties with higher yield potential and resistance to multiple stresses (drought, flood, salinity) will be the key to maintain yield stability. Improvement in germplasm of important crops for heat-stress tolerance should be one of the targets of breeding programme. Similarly, it is essential to develop tolerance to multiple abiotic stresses as they occur in nature. The abiotic stress tolerance mechanisms are quantitative traits in plants. Germplasm with greater oxidative stress tolerance may be exploited as oxidative stress tolerance is one example where plant's defense mechanism targets several abiotic stresses. Similar to the research efforts on conversion of rice from C_3 to C_4 crop, steps should be taken for improvement in radiation-use efficiency of other crops as well. Improvement in water-use and nitrogen-use efficiencies is being attempted since long. These efforts assume more relevance in the climate change scenarios as water resources for agriculture are likely to dwindle in future. Nitrogen-use efficiency may be reduced under the climate change scenarios because of high temperatures and heavy precipitation events causing volatilization and leaching losses. Apart from this, for exploiting the beneficial effects of elevated CO_2 concentrations, crop demand for nitrogen is likely to increase.

Thus, it is important to improve the root efficiency for mining the water and absorption of nutrients. Exploitation of genetic engineering for 'gene pyramiding' has become essential topool all the desirable traits in one plant to get the 'ideal plant type' which may also be 'adverse climate-tolerant' genotype. Farmers need to be provided with cultivars with a broad genetic base. Their adaptation process could be strengthened with availability of new varieties having to lerance to drought, heat and salinity and thus, minimize the risks of climatic aberrations. Similarly, development of varieties is required to offset the emerging problems of shortening of growing season and other vagaries of production environment. Farmers could better stabilize their production system with basket of technological options.

2. Crop Diversification :

Diversification of crop and livestock varieties, including replacement of plant types, cultivars, hybrids, and animal breeds with new varieties intended for higher drought or heat tolerance, are being advocated as having the potential to increase productivity in the face of temperature and moisture stresses. Diversity in the seed genetic structure and composition has been recognized as an effective defense against disease and pest outbreak and climatic hazards. Moreover, demand for high-value food commodities, such as fruits, vegetables, dairy, meat, eggs and fish is increasing because of growing income and urbanization. This is reducing the demand for traditional rice and wheat. Diversification from rice-wheat towards high-value commodities will increase income and result in reduced water and fertilizer use. However, there is a need to quantify the impacts of crop diversification on income, employment, soil health, water use and green house gas emissions. A significant limitation of diversification is that it is costly in terms of the income opportunities that farmers forego, i.e., switching of crop can beexpensive, making crop diversification typically less profitable than specialization. Moreover, traditions can often be difficult to overcome and will dictate local practices.

3. Changes in Land-use Management Practices :

Changing land-use practices such as the location of crop and livestock production, rotating or shifting production between crops and livestock, shifting production away from marginal areas, altering the intensity of fertilizer and pesticide application as well as capital and labour inputs can help reduce risks from climate change in farm production. Adjusting the cropping sequence, including changing the timing of sowing, planting, spraying, and harvesting, to take advantage of the changing duration of growing seasons and associated heat and moisture levels is another option. Altering the time at which fields are sowed or planted can also help farmers regulate the length of the growing season to better suit the changed environment. Farmer adaptation can also involve changing the timing of irrigation or use of other inputs such as fertilizers.

4. Adjusting Cropping Season :

Adjustment of planting dates to minimize the effect of temperature increase- induced spikelet sterility can be used to reduce yield instability, by avoiding having the flowering period to coincide with the hottest period. Adaptation measures to reduce the negative effects of increased climatic variability as normally experienced in arid and semi-arid tropics may include changing of the cropping calendar to take advantage of the wet period and to avoid extreme weather events (e.g., typhoons and storms) during the growing season. Cropping systems may to be changed to include growing of suitable cultivars (to counteract compression of crop development), increasing crop intensities (i.e., the number of successive crop produced per unit area per year) or planting different types of crops. Farmers will have to adapt to changing hydrological regimes by changing crops.

5. Efficient Use of Resources :

The resource-conserving technologies (RCTs) encompass practices that enhance resource- or input-use efficiency and provide immediate, identifiable and demonstrable economic benefits such as reduction in production costs; savings in water, fuel and labour requirements; and timely establishment of crops, resulting in improved yields. Yields of wheat in heat- and water-stressed environments can be raised significantly by adopting RCTs, which minimize unfavourable environmental impacts, especially in small and medium-scale farms. Resource conserving practices like zero-tillage (ZT) can allow farmers to sow wheat sooner after rice harvest, so the crop heads and fills the grain before the onset of pre monsoon hot weather. As the average temperatures in the region rise, early sowing will become even more important for wheat. Field results have shown that the RCTs are increasingly being adopted by farmers in the rice-wheat belt of the Indo-Gangetic Plains because of several advantages of labour saving, water saving, and early planting of wheat. The RCTs in rice-wheat system also have pronounced effects on mitigation of greenhouse gas emission and adaptation to climate change. These approaches of crop management should be coupled with the measures of crop improvement for wider adaptation to climate change. Soil and water management is highly critical for adaptation to climate change. With higher temperatures and changing precipitation patterns, water will further become a scarce resource. Serious attempts towards water conservation, water harvesting improvement in irrigation accessibility, and water-use efficiency will become essential for crop production and livelihood management. Farmers have to be trained and motivated for adopting on-farm water conservation techniques, micro-irrigation systems for better water-use efficiency, selection of appropriate crops, etc. Principles of increasing water infiltration with improvement in soil aggregation, decreasing runoff with use of contours, ridges, vegetative hedges, etc. and reducing soil evaporation with use of crop residues mulch could be employed for better management of soil-water.

6. Relocation of Crops in Alternative Areas :

Climate change in terms of increased temperature, CO_2 level, droughts and floods would affect production of crops. But, the impact will be different across crops and regions. There is a need to identify the crops and regions that are more sensitive to climate changes/ variability and relocate them in more suitable areas. For example, it is apprehended that increased temperature would affect the quality of crops, particularly important aromatic crops such as basmati rice and tea. Alternative areas that would become suitable for such crops from quality point of view need to be identified and assessed for their suitability.

7. Awareness in Farmers with Technical Knowledge :

Farmers in developing countries of the world, often poor and marginal, are experimenting with the climatic variability for centuries. There is a wealth of knowledge on the range of measures that can help in developing technologies to overcome climate vulnerabilities. There is a need to harness that knowledge and fine-tune them to suit the modern needs. Traditional ecological knowledge of people developed and carried which have stood the test of time could provide insights and viable options for adaptive measures. Anthropological and sociological studies have highlighted the importance of community based resource management and social learning to enhance their capacity to adapt to the impacts of future climate change. Tribal and hill knowledge systems are pregnant with potential indigenous practices used for absorption and conservation of rainwater, nutrient and weed management, crop production and plant protection. Their belief systems have effectively helped in weather forecasting and risk adjustment in crop cultivation. During the course of their habitation, the indigenous people of Himalayan terrain region through experience, experimentation and accumulated knowledge, have devised ways of reducing their vulnerability to natural hazards. Studies have shown that their understanding was fairly evolved in the matters of earthquake, landslide and drought and they have devised efficient ways of mitigating the effect of natural or climatic changes.

8. Improved Pest Management :

Changes in temperature and variability in rainfall would affect incidence of pests and disease and virulence of major crops. It is because climate change will potentially affect the pest/ weed- host relationship by affecting the pest/ weed population, the host population and the pest/weed-host interactions. Some of the potential adaptation strategies could be:

a. developing cultivars resistance to pests and diseases
b. adoption of integrated pest management with more emphasis on biological control and changes in cultural practices
c. pest forecasting using recent tools such as simulation modeling
d. developing alternative production techniques and crops, as well as locations, that are resistant to infestations and other risks.

Management of pests and diseases with use of resistant varieties and breeds; alternative natural pesticides; bacterial and viral pesticides; pheromones for disrupting pest reproduction, etc. could be adopted for sustainability of agricultural production process. Bioagents have a crucial role in pest management, hence practices to promote natural enemies like release of predators and parasites; improving the habitat for natural enemies; facilitating beetle banks and flowering strips; crop rotation and multiple cropping should be integrated in pest management practices. Reduction in use of pesticides will also help in reducing carbon emissions.

9. Better Weather Forecasting :

Weather forecasting and early warning systems will be very useful in minimizing risks of climatic adversaries. Information and communication technologies (ICT) could greatly help the researchers and administrators in developing contingency plans.

10. Crop Insurance Schemes :

Innovations in microfinance generally and in micro-insurance products specifically may aid farmers' capacity to adapt to climate change. Although microfinance has seen widespread success as a development intervention, many poor farmers continue to lack low-cost access to financial services such as savings and credit. In the absence of these services, farmers often face serious constraints in their responses to both good and bad harvests and in their ability to adopt new technologies. The microfinance movement has significant momentum and will likely continue spreading into poor rural areas. Compared to microfinance, micro-insurance innovation and availability is much more limited. There is requirement to provide government subsidies and insurance on farming activities to reduce the risk faced by high rainfall, hail, drought, pests, etc. For this purpose efforts should be taken by public sector development community, private banks and re-insurance firms, NGOs, etc.

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