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BLOCK I: BIODIVERSITY AND ENVIRONMENT

UNIT 1 - BIODIVERSITY AND ENVIRONMENT

Highlights of the Unit

- Objectives
- Introduction
- What is biodiversity? Types.
- What is environment?
- Biodiversity and agriculture
- Biodiversity conservation methods
- In situ and Ex situ conservation
- Let's sum up
- Check Your Progress
- Further readings/references

1.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Concept of biodiversity and environment
- Existing and identified Biodiversity
- Significance of Biodiversity
- Biodiversity and Agriculture
- Reasons and impact of Extinction of Biodiversity
- Biodiversity Conservation Methods

1.1 INTRODUCTION

For much of the time man lived in a hunter-gather society and thus depended entirely on biodiversity for sustenance. But, with the increased dependence on agriculture and industrialization, the emphasis on biodiversity has decreased. Indeed, the biodiversity, in wild and domesticated forms, is the source for most of humanity, food, medicine, Clothing and housing, much of the cultural diversity and most of the intellectual and spiritual inspiration. It is, without doubt, the very basis of life. Further that, a quarter of the earth's total biological diversity amounting to 1.7 million species, which might be useful to mankind in one way or other, would be at serious risk of existence over the next 2-3 decades. On realization that the erosion of biodiversity may threaten the very existence of life has awakened man to take steps to conserve it. Hence, it is essential to have comprehensive knowledge of Biodiversity.

1.2 WHAT IS BIODIVERSITY?

Biodiversity is shortened form of Biological diversity that refers to the rich and diverse energy of living organisms of all species, the genes they contain and the ecosystem they constitute.

"Biological diversity means the variability among living organisms from all sources including interalia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species and of ecosystems"

Biodiversity is also defined as the existence of variability among living organisms on the earth, including the variability within and between species, and within and between ecosystems.

1.3 WHAT IS THE ENVIRONMENT?

An environment refers to the surroundings or setting in a particular area. The environment has two components: biotic and abiotic. The biotic component comprises the plants and animals, as well as the microorganisms in a particular habitat. Abiotic factors involve the topography, soil, atmosphere, sunlight, water, and nutrients among others. An environment is a place where living things reside together with other non-living things. The earth has an environment which has the elements of soil, water, air, fire, as well as living and non-living things. The earth's environment is constantly changing depending on the existing elements. It may also be affected by man-made developments happening all around us. The environment, in a holistic sense is our surroundings and everything we see, feel, smell, and hear around us.

1.4 TYPES OF BIODIVERSITY

Biodiversity is considered at three levels i.e. Genetic diversity, Species diversity and Ecosystem diversity

1.4.1 Genetic Diversity: It is the variation in genes that exists within a species. Genetic diversity corresponds to the variety of genes contained in plants, animals, fungi and micro-organisms. It occurs within a species as well as between species. For example, poodles, German shepherds, and golden retrievers are all dogs, but they all are different in look, color, and abilities.

The diversity in wild species makes the 'gene pool' from which crops and domestic animals have been developed over thousands of years.

1.4.2 Species Diversity: Species diversity refers to the variety of different species of plants, animals, fungi and organisms that are present in a region. It is estimated that there are above 30 million species on the earth. Species diversity is a part of diversity. Even within a small pond, we can notice a great variety of species. Species diversity differs

from ecosystem to ecosystem. For example in a tropical ecosystem more diversity is found than in a temperate ecosystem. The most diverse group of species is invertebrates - animals without backbones.

At present, conservation scientists have been able to identify and categorize about 1.8 million species on earth. Many new species are being identified. Areas that are rich in species diversity are called 'hotspots' of diversity.

1.4.3 Ecosystem Diversity: It is the diversity of ecosystems, natural communities and habitats. In other words, ecosystem diversity refers to the variety of ways that species interact with each other and their environment. Tropical or temperate forests, grasslands, hot and cold deserts, wetlands, rivers, mountains and coral reefs are instances of ecosystem diversity.

Each ecosystem corresponds to a series of complex relationships between biotic (living) and abiotic (non-living) components.

1.4.4 EXISTING AND IDENTIFIED BIODIVERSITY

It is estimated that there exist 5-50 million species of living forms on the earth. However, only 1.7 million have been identified so far. These include 4, 27,205 species of green plants, fungi, bacteria, and viruses; 61,917 species of vertebrates and protochordate and 12, 32,490 species of invertebrates including Protista.

1.4.5 SIGNIFICANCE OF BIODIVERSITY

Ecological role of biodiversity: All species provide some kind of function to an ecosystem. They can capture and store energy, produce organic material, decompose organic material, help to recycle water and nutrients throughout the ecosystem, control erosion or pests, fix atmospheric gases, and help regulate climate. These physiological processes are important for ecosystem function and human survival. A diverse ecosystem will be able to withstand environmental stress and consequently more productive.

The loss of a species is thus likely to decrease the ability of the system to maintain itself or to recover from damage or disturbance. Just like a species with high genetic diversity, an ecosystem with high biodiversity may have a greater chance of adapting to environmental change. In other words, an ecosystem with more species is likely to be more stable than an ecosystem with a fewer number of species.

Economic role of biodiversity: For all humans, biodiversity is first a resource for daily life. The first one is crop diversity, which is also called agrobiodiversity.

Biodiversity is a reservoir of resources to be drawn upon for the manufacture of food, pharmaceutical, and cosmetic products.

Some of the important economic commodities that biodiversity supplies to humankind are:

a. Modern agriculture: Biodiversity is used as a source of material for breeding improved varieties, and as bio-pesticides, bio-fertilizers, etc.

b. Food: Crops, livestock, forestry, and fish. Mangroves and coral reefs in coastal zone support fisheries.

c. Medical drugs: Wild plant species have been used for medicinal purposes since before the beginning of recorded history. For example, quinine comes from the cinchona tree (used to treat malaria), digitalis from the foxglove plant (chronic heart trouble), and morphine from the poppy plant (pain relief). According to the National Cancer Institute, over 70% of the promising anticancer drugs come from plants in the tropical rainforests. It is estimated that of the 2, 50,000 known plant species, only 5,000 have been investigated for possible medical applications.

d. Industry: Fibers are used for clothing, wood for shelter, energy, and various other uses. Biodiversity may be a source of energy (such as biomass). Other industrial products are oils, fragrances, dyes paper, waxes, rubber, latexes, resins, poisons, and cork, which all can be derived from various plant species. Supplies from animal origin include wool, silk, fur, leather, lubricants, and waxes. Animals may also be used as a mode of transport.

1.4.6 Aesthetic and cultural benefits: Biodiversity has great aesthetic value. Examples of aesthetic value include eco-tourism, bird watching, wildlife, gardening, etc. Eco-tourism is a source of economical wealth for many areas, such as many parks and forests, where wild nature and animals are a source of beauty and joy for many people. Biodiversity is also part of many cultural and religious beliefs. In many Indian villages and towns, plants like Ocimum sanctum (Tulsi), Ficus religiosa (Pipal), and Prosopis cineraria (Khejri) and various other trees are considered sacred and worshipped by the people. Several birds, animals and even snake have been considered sacred. Also, we recognize several animals as symbols of national and heritage.

1.4.7 Scientific role of biodiversity: Biodiversity is important because each species can give scientists some clue as to how the life evolved and will continue to evolve on Earth. In addition, biodiversity helps scientists understand how life functions and the role of each species in sustaining ecosystems.

1.4.8 Threatened Biodiversity: The loss of biological diversity is a global crisis. There is hardly any region on the Earth that is not facing ecological catastrophes. Of the 1.7 million species known to inhibit the Earth (human are just one of them), one third to one fourth is likely to extinct within the next few decades. Biological extinction has been a natural phenomenon in geological history. But the rate of extinction was perhaps one species every 1000 years. But man's intervention has speeded up extinction rates all the more. Between 1600 and 1500, the rate of extinction went up to one species every 10 years. It is

estimated that about 50 species are being driven to extinction every year, bulk of them in tropical forest, due to human interference.

1.4.9 Listing of threatened biodiversity: To highlight the legal status of rare species for the purpose of conservation, the International Union for Conservation of Nature and Natural Resources (IUCN) has established the following five main conservation categories:

1. **Extinct species** that are no longer known to exist in the wild. Searches of localities where they were once found and of other possible sites have failed to detect the species.
2. **Endangered species** that have a high likelihood of going extinct in the near future.
3. **Vulnerable species** that may become endangered in the near future because populations of the species are decreasing in size throughout its range.
4. **Rare species** that have small total numbers of individuals often due to limited geographical ranges or low population densities.
5. **Insufficiently known species** that probably belong to one of the conservation categories but are not sufficiently well known to be assigned to a specific category.

These categories were named as Red list categories. The IUCN Red List is the catalogue of threatened species that are facing the risk of extinction. This list aims to impart information about the urgency and scale of conservation problems to the public, environmentalists and policy makers. On the global level, the IUCN published Red Data Book, name given to the book dealing with threatened pants and animals of any region.

1.4.10 REASONS FOR EXTINCTION OF BIODIVERSITY

Destruction of habitat: The natural habitat may be destroyed by man for his settlement, grazing grounds, agriculture, mining, industries, highway construction, drainage, dam building, etc. As a consequence of this, the species must adapt to the changes, move elsewhere or may succumb to predation, starvation or disease and eventually die. For example, out of 370 butterfly species 70 are at the brink of extinction which are available in the Ghats.

Hunting: From time immemorial, man has hunted for food. Commercially, wild animals are hunted for their products such as hide and skin, tusk, antlers, fur meat, pharmaceuticals, perfumes, cosmetics and decoration purposes. For example, in India, rhino is hunted for its horns, tigers for bones and skin, musk deer for musk (have medicinal value), elephant for ivory, gharial and crocodile for their skin, and jackal for thriving fur trade in Kashmir.

Overexploitation: Excessive use of a resource is than its normal revival. This is one of the main causes of the loss of not only economic species but also biological curiosities like the insectivorous and primitive species and other taxa needed for teaching or laboratory (like

Nepenthes, Gnetum, Psilotum etc.). Example, exploitation of wild mango trees for plywood, whales hunting for tallow and Plants of medicinal value.

Collection for zoo and research: Animals and plants are collected throughout the world for zoo and biological laboratories for study and research in science and medicine. For example, primates such as monkey and chimpanzees are used for research as they have anatomical, genetic and physiological similarities to human beings.

Introduction of exotic species: Native species are subjected to competition for food and space due to competition for food and space due to introduction of exotic species. For example introduction of goats and rabbits in the Pacific and Indian regions has resulted in destruction of habitats of several plants, birds and reptiles.

Control of pests: Pest control measures generally kill predators and beneficial insects that are a component of balanced ecosystem and may also indiscriminately poison non-target species.

Pollution: Pollution alters the natural habitat. Water pollution especially is injurious to the biotic components of estuary and coastal ecosystem. Toxic wastes entering the water bodies disturb the food chain and so to the aquatic ecosystems. Insecticides, pesticides, Sulphur dioxide, nitrogen oxides, acid rain, ozone depletion and global warming adversely effects the plant and animal species.

Deforestation: It results from population settlement, shifting cultivation, development projects. In our country, the current rate of deforestation is 13,000 sq. km annually. It is presumed that in coming years, the global loss of biodiversity from deforestation alone would be 100 species every day.

Other factors: Other ecological factors that may also contribute to the extinction of wildlife are as follows:

a. **Distribution range** – The smaller the range of distribution, the greater the threat of extinction.
b. **Degree of specialization** – The more specialized an organism is, the more vulnerable it is to extinction.
c. **Position of the organism in the food chain –** The higher the position of the organism in food chain, the more susceptibility for loss.
d. **Reproductive rate –** Large organisms tend to produce fewer offspring at widely spaced intervals.
e. **Outbreaks of diseases –** cause for the decline in wildlife species.
f. **Loss of gene flow –** The individuals of plant and animal life may decline to the significant levels as a result of loss of gene flow.
g. **Substitution –** During the process of evolution an existing species may be replaced by ecologically another one.

h. In developing counties like India, the development policies and projects have rarely been sensitive to the need for biodiversity conservation, and for local communities. The government's failure to remove poverty and curb middle-class consumerism has led conditions in which rational natural resources management assumes low priority.

1.5 BIODIVERSITY AND AGRICULTURE

Agricultural diversity can be divided into two categories: intraspecific diversity, which includes the genetic variety within a single species like the potato (*Solanumtuberosum*) that is composed of many different forms and types (e.g. in the U.S. they might compare russet potatoes with new potatoes or purple potatoes, all different, but all part of the same species, *S. tuberosum*). Intraspecific diversity, the variety of alleles within a single species, also offers us choice in our diets (Short, medium and long duration varieties)

The other category is interspecific diversity and refers to the number and types of different species. Example, different crops like potatoes and also carrots, peppers, lettuce etc.

Agricultural diversity can also be divided as 'planned' diversity or 'associated' diversity. Planned diversity includes the crops which a farmer has encouraged, planted or raised (e.g. crops, cereals, legumes and livestock), which can be contrasted with the associated diversity that arrives among the crops, uninvited (e.g. pests, weed species and pathogens etc.

The associated biodiversity could be controlled by using suitable biologically destructive pesticides, mechanized tools and transgenic engineering techniques, then to rotate crops.

Integrated pest management strategies are more labor-intensive, but generally less dependent on capital, biotechnology and energy.

a. The Irish potato blight of 1846 was a major factor in the deaths of one million people and the emigration of about two million. It was the result of planting only two potato varieties, both vulnerable to the blight, *Phytophthorainfestans*, which arrived in 1845.
b. When rice grassy stunt virus struck rice fields from Indonesia to India in the 1970s, 6,273 varieties were tested for resistance. Only one was resistant, an Indian variety and known to science only since 1966. This variety formed a hybrid with other varieties and is now widely grown.
c. Coffee rust attacked coffee plantations in Sri Lanka, Brazil and Central America in 1970. A resistant variety was found in Ethiopia. The diseases are themselves a form of biodiversity.
d. Monoculture (which has limited biodiversity) is considered as a contributing factor to several agricultural disasters including the European wine industry collapse in the late 19th century and the US southern corn leaf blight epidemic of 1970.

Although about 80 percent of humans' food supply comes from just 20 kinds of plants, humans use at least 40,000 species. Many people depend on these species for food, shelter and clothing. Earth's surviving biodiversity provides resources for increasing the range of food and other products suitable for human use, although the present extinction rate shrinks that potential.

Never follow monocultures and even if followed use different varieties of same crop.

1.6 IMPACT OF LOSS OF BIODIVERSITY

a. Global warming and climate change
b. Increased pollution
c. Soil erosion and loss of fertility
d. Decomposition rate by microbes and nutrient cycling is altered
e. Reduced gene pool- affects speciation and food chain is altered
f. Alteration in hydrological cycle

1.7 BIODIVERSITY CONSERVATION METHODS

We must make every effort to preserve, conserve and manage biodiversity. Protected areas, from large wilderness reserves to small sites for particular species and reserves for controlled uses, should be main guide. India is the second most populous country, and therefore any plan for conservation must consider socio-economic development which threatens the biotic resources of the country. Furthermore, as our economy is predominantly rural and agrarian based, policy makers should realize that conservation and sustainable utilization of biodiversity should be considered in all developmental programmes. To conserve the biodiversity, the immediate task will be to devise and enforce time bound programme for saving plant and animal species as well as habitats of biological resources. Action plan for conservation, therefore, must be directed to:

- Inventorization of biological resources in different parts of the country including the island ecosystem;
- Conservation of biodiversity through a network of protected areas including National Parks, Wildlife Sanctuaries, Biosphere Reserves, Tiger Reserves, Marine Reserves, Gene Banks, Wetlands, Mangroves, Coral Reefs, etc.;
- Rehabilitation of rural poor/tribes displaced due to creation of protected areas;
- Conservation of micro-organisms which help in reclamation of wastelands and revival of biological potential of land;
- Protection and sustainable use of genetic resources/ germplasm through appropriate laws and practices;
- Regular access to biological resources of the country with the purpose of securing equitable share in benefits arising out of the use of biological resources and associated knowledge relating to it;

- Control of over-exploitation through TRAFFIC, CITES and other agencies, and also through treaties/protocols//environmental protection laws at National/International level;
- Protection of domesticated plant and animal species in order to conserve indigenous genetic diversity;
- Maintenance of corridors between different nature reserves for the possible migration of species in response to climate, or any other disturbing factor;
- Support for protecting traditional skills and knowledge for conservation;
- Multiplication and breeding of threatened species through modern techniques of tissue culture and biotechnology;
- Discouragement of monoculture introduction; and
- Restriction on introduction of exotic species without adequate investigations.

1.8 IN SITU CONSERVATION AND EX SITU CONSERVATION

1.8.1 In Situ Conservation: In situ conservation means the conservation of ecosystem and natural habitat and maintenance and recovery of viable population of species in the natural surrounding where they have developed their distinctive characteristics. In situ conservation methods pertain to conserving animals and plants in their natural habitats. This involves establishment of protected areas, national parks, sanctuaries, biosphere reserves, reserve forests etc.

National parks: A National Park is an area of land set aside to conserve the scenery (or environment) and natural objects and the wildlife there in. All kinds of destruction, exploitation and removal of wildlife and damage to the habitat of any animal are strictly prohibited inside a National park. Grazing of domestic animals is also prohibited.

Wildlife sanctuaries (WLS): Similar to the National park, a wildlife sanctuary is dedicated to protect wildlife, but it considers the conservation of species only and also the boundary of it is not limited by state legislation. No person allowed moving freely inside the sanctuary except with the permission of the authorities. The permanent residents of the area are bound to perform certain duties such as helping in controlling fire damage, to report about dead animals and render all kinds of help in resisting the offenders.

Conservation reserves: Conservation Reserves can be declared by the State Governments in any area owned by the Government particularly the areas adjacent to National Parks and Sanctuaries and those areas which link one Protected Area with another. Conservation Reserves are declared for the purpose of protecting landscapes, seascapes, flora and fauna and their habitat. The rights of people living inside a Conservation Reserve are not affected.

Community reserves: Community Reserves can be declared by the State Government in any private or community land, not comprised within a National Park, Sanctuary or a Conservation Reserve, where an individual or a community has volunteered to conserve wildlife and its habitat. Community Reserves are declared for the purpose of protecting fauna, flora and traditional or cultural conservation values and practices. As in the case of a Conservation Reserve, the rights of people living inside a Community Reserve are not affected.

Biosphere reserves: Biosphere reserves have been described as undisturbed natural areas for scientific study as well as areas in which conditions of disturbance are under control. They have been set aside for ecological research and habitat preservation. The fifteen Biosphere Reserves set up in the country so far not only aim to protect representative ecosystems, but also serve as laboratories for evolving alternative models of development.

Wetlands, mangroves and coral reefs

Wetlands: National Wetland Committee was constituted in 1989. The committee in the same year identified 16 wetlands, which need conservation measures and this has been increased to 26.

Mangroves and coral reefs: The National Environmental Policy, 2006 recognizes that mangroves and coral reefs are important coastal environmental resources. They provide habits for marine species, protection from extreme weather events, and a resource base sustainable tourism.

Endangered wildlife special projects: These special projects have been designated for species specific management of endangered species and their habitats.

- **Project tiger:** In India Project Tiger was launched in 1973 with an objective "to ensure maintenance of a viable population of tigers in India for scientific, economic, aesthetic, cultural and ecological values and to preserve for all times areas of biological importance as a national heritage for benefit and enjoyment of the people".
- **Project elephant**: This was launched in 1992 with the aim at ensuring long term survival of identified viable populations of elephant population. There have been drawn lines to restore the lost and degraded habitats of elephant including creation of corridors for their migration, mitigation of man-elephant conflict and establishment of data base on the migration and population dynamics of elephants
- **Gir lion project:** The Gir forest in Saurashtra peninsula of Gujarat is unique as the only surviving habitat of the Asian lion Panthera leonpersica. At present in whole of the Asia, this lion is found only in Gir forest of Gujarat.
- **Crocodile breeding project**: The project was established for development of three species of crocodiles in India

(i) Saltwater or estuarine crocodile (Crocodylusprosus)
(ii) Freshwater, swamp crocodile mugger (C. palustris), and
(iii) Gharial (Gavialisgangeticus)

- **Rhino's conservation:** 'The Conservation of Rhinos in Assam was introduced in 1987 and is continued for effective and intensive management of rhino habitats.
- **Snow-leopard project**: This is being taken to create 12 snow-leopard reserves throughout the Himalayas.

Preservation plots: Preservation plots are areas where chief types of forests are identified for preservation and conservation of biological diversity contained in them. There are over 309 preservation plots all over the country, 287 in natural forest and 22 in plantation forest.

World heritage sites: India ratified the World Heritage Convention in 1977 and since then five natural sites have been taken over as areas of outstanding universal value. These sites are listed below.

a. Kaziranga National Park, Assam
b. Keoladeo National Park Rajasthan
c. Manas National Park, Assam
d. Nanda Devi National Park, Uttaranchal
e. Sunderbans National Park West Bengal

Sacred forest and sacred lakes: Sacred forests are the forest patches of varying dimensions protected by the tribal communities on account of their religious sanctity accorded to them. These represent islands of pristine forest i.e. most undisturbed forests with no human impact and have been free from all disturbances despite they are frequently surrounded by highly degraded lands. Many states in our country, such as Maharashtra, Karnataka, Meghalaya and Kerala have sacred forests which are serving as refugee for many endemic, rare and endangered taxa. Similarly, some fresh water lakes are also serving the purpose of protection of aquatic flora water lakes are also serving the purpose of protection of aquatic flora and fauna.
For example: Khecheopalri Lake in Sikkim has been declared sacred by the people to save aquatic life from being degraded.

1.8.2 Ex Situ Conservation: Ex situ conservation means the conservation of biological diversity components outside their natural habitat. It involves cultivation of rare plants/rearing of threatened animals outside of their natural habitats and also holding of plants and animal species in botanical and zoological gardens and in arboretums or store them in the form of seeds in seed bank (gene banks) or some other suitable forms by means of tissue cultures techniques.
Zoological parks: There are roughly 5, 00,000 mammals, birds, reptiles and amphibians in captivity in zoos throughout the world.

Zoos contribute in many ways to the conservation of biodiversity:

- They propagate and reintroduce endangered species;
- They serve as centers for research to improve management of captive and wild populations;
- They raise public awareness for biotic improvement.
- They enlighten the public that animals are equally important and are essential for the life support system.

Rescue centers: Rescue centers, are for rehabilitation of circus animals, consequent upon ban on performance of wild animals in Circuses. Five rescue centers were are at Chennai, Visakhapatnam, Tirupati, Bannerghatta (Bangalore) and Nahargarh (Jaipur).

Aquaria: Aquaria are centers for the captive propagation of threatened freshwater species. They are meant for restoration and protection of natural habitats, provide protection against loss of wild species and help educate the public on threats to fishes.

Botanical gardens: Botanical gardens conservation of species extends beyond the preservation of species threatened in wild. Botanical gardens supply plants for research and horticulture, thereby reducing pressure on wild population and are important education resources.

Gene banks: A gene bank is a facility/institution where valuable plant materials likely to become irretrievably lost in the wild or in cultivation can be preserved in viable condition. Gene banks conserve stocks of both seeds and vegetative plant parts.

Pollen/semen conservation: Preservation of pollen and spores is of significant value for conservation of biodiversity of important flowering and spore bearing plants. The procedure for institution of pollen and spore banks is almost similar to that of gene banks. A pollen bank can be an extremely powerful tool in plant breeding since it frees breeders from the tyranny of time and also, it is useful in self-sterilized plant species.

Tissue culture techniques: Tissue culture technique provides a means of multiplying "endangered species" with possibility of reintroducing them into their original habitats where they are becoming rare. A large number of genotypes can be stored in a relatively small area in culture vessels and generally at a fraction of cost of growing and maintaining large living collections in the field.

Through tissue culture technique it is now also possible to preserve animal cells, spermatozoa, ovarian and embryonic tissues as well as whole animals embryos under extremely low temperature in liquid nitrogen at -196 ^{o}C (cryopreservation). These cultures can be used for livestock breeding programmes.

Recombinant DNA Technology: The recombinant DNA technology allows us to clone any DNA in Escherichia coli, and soon it will hopefully be possible to extend such cloning to yeast and other organisms. Cloned DNA, therefore, appears to be an attractive candidate for genetic conservation.

Role of electronics tools: Development of electronics as a tool in the conservation of wildlife should be given prime importance as electronic devices are helpful in aerial

photography, data collection of plants and animals, detection of forest fires, educational programmes and monitoring of animal movements.

Efforts of individuals for biodiversity conservation: Romulus Whitaker, a wild life enthusiast learnt snake catching from Irulas (expert snake catchers in Tamil Nadu and crocodile catching from Papua New Guinea. He later established a 'Madras Snake Park' which has 31 species of Indian snakes, all three species of Indian crocodiles, four species of exotic crocodiles, three species of Indian turtles and five species of lizards. Many species of reptiles, including endangered species of Indian python is subjected to captive breeding. He has also established a Crocodile bank – the gene bank for crocodile. Snake Park is of great educational, scientific and conservation value. Whitaker's life and work throws light on that a single individual can make a significant contribution to the conservation of biodiversity through passion and dedication.

Team work: Team of scientists from various disciplines like Botany, Zoology, Agriculture, Horticulture, Soil Science, Pharmacology, Engineering, Silviculture and Economics and trained foresters, administrators, forest lovers, biodiversity experts and local village representatives - should be integrated in managing, promoting and implementing conservation programmes.

1.9 LET'S SUM UP

It is imperative that the phenomenon of biodiversity is very vast, complex and interdependent and there is no single over-arching effect of diversity on either productivity or stability. The realized effects will depend heavily on environmental context and the time scale over which the effects are studied. However, it has become obvious that biodiversity is indeed important for both managed and natural ecosystems, though the relative contributions of diversity and composition remain unclear. If current human growth and resource management patterns do not change, it is likely that we will lose many important species, and the ecosystems of the world may never recover. Therefore it is necessary to acquaint and understand biodiversity comprehensively and take collective measures in conservation of existing biodiversity and retrieve back eroded or lost biodiversity. It is also duty of legislators to understand the basic science in order to maintain diversity at required levels.

1.10 CHECK YOUR PROGRESS

1. What is biodiversity? What are different types of biodiversity?
2. What is environment? What are the existing and identified living forms on earth?
3. How some species benefit eco system? What is scientific role of biodiversity?
4. Name important economic commodities that biodiversity supplies mankind.
5. What are two forms of Agriculture diversity classifications?
6. Name three crops which were affected due to lack of biodiversity?
7. How many species humans utilized as food?

8. Write five categories of threatened biodiversity specie.
9. List nine main factors for extinction of biodiversity.
10. What are main impacts of biodiversity loss?
11. What is meant by in situ conservation method for biodiversity?
12. What are biosphere reserves? What are sacred forests?
13. What is meant by ex situ biodiversity measures? What are rescue centers?
14. How electronic tools help in biodiversity conservation?
15. Name team of scientists in managing, promoting and implementing biodiversity conservation

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UNIT 2: SOIL AND WATER CONSERVATION

Highlights of the Unit

- Objectives
- Introduction
- Types of soil and water erosion
- Causes of soil erosion
- Factors determining soil erosion
- Soil erosion prediction
- Environmental and agricultural consequences of soil erosion
- Soil and water conservation measures
- Agricultural conservation measures
- Let's sum up
- Check Your Progress
- Further reading/ references

2.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Types of Soil and Water Erosion
- Causes of Soil erosion
- Factors determining Soil Erosion
- Soil and Water Conversation Measures
- On-Farm Interventions
- Agricultural conservation measures

2.1 INTRODUCTION

Conservation of soil and water resources is important for sustainability of agriculture and environment. Soil and water resources are under immense pressure due to ever increasing population thereby ensuing growing demand for food, fibre and shelter. Soil and water resources are being deteriorated due to different anthropogenic and natural factors. Soil erosion may lead to the significant loss of soil productivity and thus may lead to the desertification under several conditions. Water and wind are the major agencies which are responsible for soil erosion. Deforestation, over-grazing, intensive cultivation, mismanagement of cultivated soils and intensive urbanization are major factors triggering the soil erosion. For sustainable agriculture and environment, it is pertinent to protect the soil resources against erosion. Different control measures should be adopted to protect the soil resources against erosion. The concept of soil conservation cannot be materialized without conserving and efficient use of water resources. It is therefore pre-requisite that soil conservation practices should be adopted.

The soil covering the Earth surface has taken millions of years to develop. The rate of soil formation is very slow (during every 100 to 400 years, only 1 cm soil is formed) and the enough soil depth is formed in 3000 to 12000 years to have a productive land. Thus, when soil, a non-renewable natural resource is ruined then it will be lost entirely. (There is an alternative theory to this. They say that good soils can be formed within short span, say two or three years with consistent and considerable bio-inputs – animal waste/ green manures – This process will enable to establish good quality soils even in deserts, within a short span. In fact, they mock at this theory of hundreds of years to form soil, etc.)– Permaculture Theory). Globally, out of 22% of the land suitable for sustaining agricultural productivity, around 5 to 7 M. ha are being lost annually due to land degradation, consequently, threatening food security of the world. Soil and water resources conservation and management is important for the welfare of the people.

2.1.1 Basic principles of soil and water conservation are:

- Increasing the time of stay of rain water thereby allowing more runoff to be absorbed
- Breaking the velocity of the runoff by intercepting the slope into shorter ones
- Protection from runoff
- Improving the soil health in terms of its physical and chemical composition; health of soils in terms of its soil-organic content and nutrients; ability to hold moisture/ humus/ ability to facilitate/ host biological actions.

2.2 TYPES OF SOIL AND WATER EROSIONS

2.2.1 Soil erosion: In agriculture, soil erosion refers to the removal of topsoil by the natural physical forces of water and wind at a greater rate than it is formed or through forces associated with farming activities such as tillage. Erosion removes the topsoil first and once this nutrient-rich layer is lost, the potential of soil to sustain plants is reduced. Without soil and plants the land becomes desert like and unable to support life. Soil erosion is a naturally occurring process that affects all landforms. Soil erosion can be classified into two major types, i.e., accelerated and geological erosion.

The normal process of weathering is geological erosion that usually happens as a part of natural soil-forming mechanisms at low rates in all soils. It is not affected by human activities as well as it happens at the period of long geological time. The processes influenced by the slow but constant geological erosion are the development and disintegration of rocks.

On the contrary, in accelerated erosion, soil erosion becomes a main anxiety and a specific threshold level is exceeded by the erosion rate and soil loss through erosion exceeds the soil formation through pedogenic processes. Anthropogenic activities such as slash-and burn agriculture, intensive and uncontrolled grazing, deforestation and burning of biomass and intensive ploughing are main factors which trigger accelerated soil erosion. The soil becomes less productive after the loss of fertile topsoil even by applying the same farm inputs. So, the control and management of soil erosion are essential. Although soil erosion cannot be eliminated but there are ways to minimize

excessive erosion and its adverse effects on agricultural production. The extent and the effects of soil erosion on yield depend on soil profile development, terrain, soil management and climatic conditions.

2.2.2 Water erosion: On global level, most severe type of soil erosion is water erosion. Detachment and movement of soil particles from its original place due to movement of water is called water erosion. Water from runoff, rain, irrigation and snowmelt may contribute to soil erosion but rainwater is the major factor which causes the movement and detachment of soil particles. The transportation of soil organic and inorganic particles with the water flowing along the slope is subsequently deposited in surface water bodies and at lower landscape positions in water erosion. The new soil reservoirs, streams or simply fill lakes are formed from these transported materials. In humid and sub-humid areas of world which are characterized by repeated rainstorms, the dominant form of erosion is wind erosion. The same problem is noticed in the land that is bare and has no vegetation like in the arid and semiarid regions that have limited precipitation in the form of intense storms (torrential rain). There are many types of water erosion: inter rill, splash, rill, gully, stream bank, and tunnel erosion. Inter rill erosion is also known as sheet and splash erosion, but these two differ in the underlying fluvial processes.

2.2.3 Raindrop or splash erosion: Raindrops strike the soil surface, scatter and then splash the soil by displacing particles from their original location. Splash erosion is initiated by hitting of the soil surface by the falling raindrops. Soil particles displace from their original position after the striking of raindrops that scatter and splash the soil. Falling drops initiate the splash erosion by hitting the soil surface. Splash of soil particles, depression formation, raindrop impacts are included in the process of splash erosion. A raindrop-soil particle momentum is formed after the hitting of raindrops to the soil surface before discharging their energy in the form of splash. These raindrops form holes or cavities after hitting the soil like small bombs of different shapes and sizes.

2.2.4 Sheet/ inter-rill erosion: Immediately after the sheet/inter-rill erosion starts runoff quickly forms small rills and part of the runoff flowing in between these rills is called sheet or inter-rill erosion. Shallow flow of water is the main reason of such type of erosion. Some soil particles in form of a thin sheet are moved away with the runoff and some settle in these small rills. The most common type of soil erosion is the sheet or inter rill erosion. About 70% of total soil is contributed by splash and inter-rill erosion and occur simultaneously with the splash erosion dominating during the initial process.
Inter-rill erosion is a function of rainfall intensity, field slope and particle detachment. The gradual removal of entire field surface in more or less uniform way starts the sheet erosion. It is a gradual process and it is not immediately obvious that the soil is being lost.

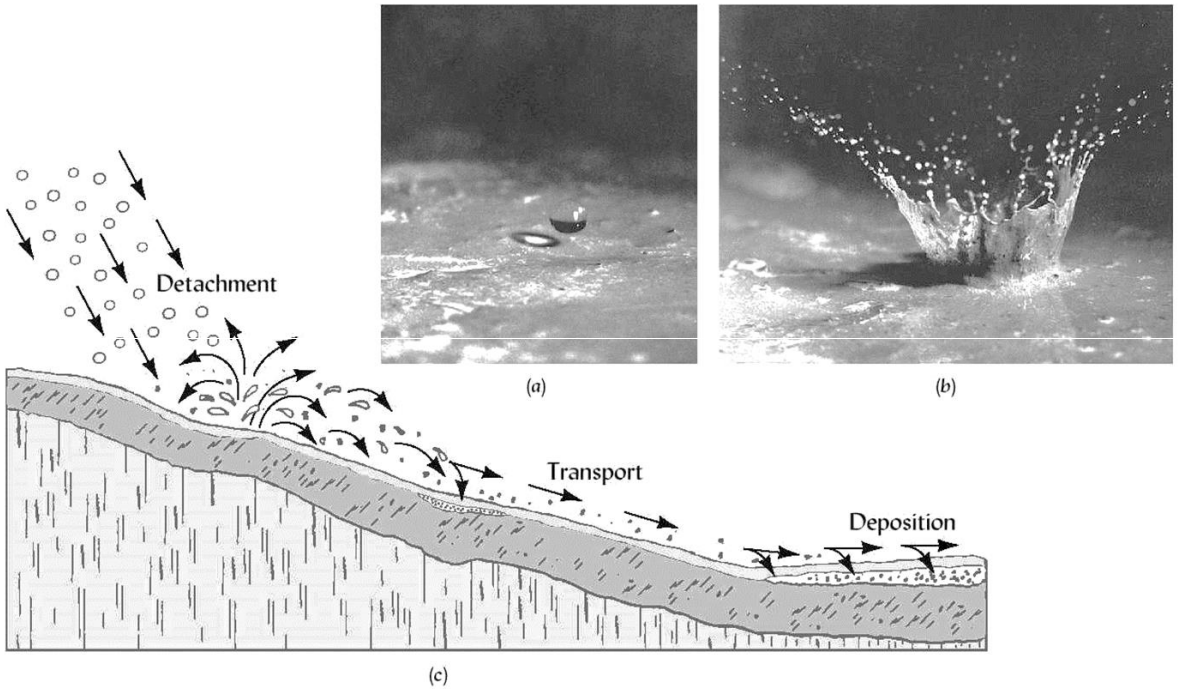

Fig 1 Sheet/ inter-rill erosion

(a) Raindrop falling on the surface
(b) Splash impact of raindrop
(c) Process of water erosion

2.2.5 Rill erosion (channel erosion): The erosion that occurs in small channels or rills is rill erosion. It is due to rigorous rather than shallow flow. The soil is eroded more quickly in small channels by the runoff water than inter-rill erosion. The soil particles creeping and flow velocity along the rill bed widen the rills. The second most common form of soil erosion is rill erosion. The tillage operations can easily manage these rills but large soil erosion might be caused especially under heavy rains. In Pakistan, erosion found in the regions of Poth war Plateau and western hilly areas is visible rill erosion.

2.2.6 Gully erosion: Formation of V- or U-shaped channels takes place in gully erosion. These gullies are formed in form of small channels with 0.3 m depth and 0.3 m width. The concentrated runoff which is joined in lower slopes is the primary mechanism of formation of these gullies in the field. Concentrated flow erosion is a term that is used to describe the erosion occurring in these channels. When the water moves down the slopes in small channels, the uneven fields demonstrate the concentrated runoff in natural swales. The entire soil profile can also be removed in confined segments by continuous gully. Increase in gully growth increases sediment transport. Gully erosion can be permanent and ephemeral. The normal tillage practices can easily remove the ephemeral gullies that contain shallow channels. On the other hand, permanent gullies require expensive means of reclamation and control as these are too large to be corrected by

regular tillage. The most common locations for gully erosion in Pakistan is Poth war Plateau especially on loess soil.

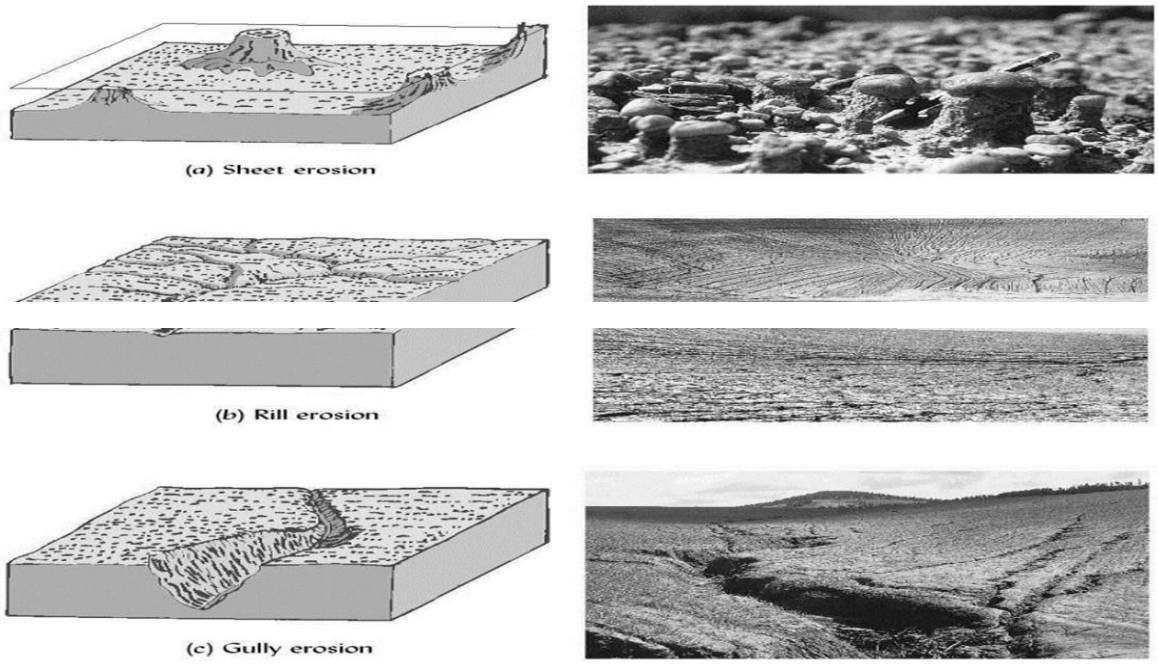

Fig 2 Types of water erosion
(a) Sheet erosion (b) Rill erosion (c) gully erosion

2.2.7 Tunnel erosion: The lands in arid and semiarid areas are highly erodible and sodic B horizon but have a stable a horizon and it is also known as pipe erosion. Tunnel erosion is initiated by the runoff in natural cracks and channels produced due to the movement of burrowing animals in subsoil layers. Due to tunnel erosion, geo-morphological and hydrological characteristics of the area are affected. These tunnels can be cured by deep ripping, repacking of soil surface, contouring, reducing of runoff ponds and diversion of heavy runoff. This type of erosion is also reduced by the vegetation that include tree and deep rooted grass species.

2.2.8 Stream bank erosion: In this type of erosion, breakdown of banks along streams, creeks, and rivers occurs due to the erosive power of runoff from uplands fields. Pedestals formation with fresh vertical cuts along streams is the reason of stream bank erosion. Exhaustive cultivation, grazing and traffic along streams, and presence of bare land accelerate stream bank erosion. This type of erosion can be reduced by planting grasses and trees, establishing engineering structures, mulching stream borders with rocks and woody materials, geo-textile fencing, and diverting runoff.

2.2.9 Wind erosion: Wind erosion occurs mainly in dry areas where soil surface is left bare. In dry regions, because of low rainfall, soil is too dry and flat to allow the wind to

carry the soil away over several consecutive days. Mostly the material carried by winds contains silt-sized particles.
Accumulation of this material is named as "loess". Normally, the areas where loess deposits are converted into soils are very fertile with deep soils. The thickness of recorded loess deposits ranges between 20 and 30 m, but it can be as thick as 335 m. Animals also play major role to cause erosion i.e. the upper part of soil is disturbed by the hooves of animals and as well as plant protective cover is removed when animals graze in land. The bare arable lands are also major problem leading to erosion.

Soil mismanagement is the key factor which results in excessive wind erosion and resulted in barren land in many arid regions. Anthropogenic activities such as deforestation and excessive tillage also lead to severe wind erosion. In arid and semiarid regions, the major factors of wind erosion are fast moving winds, low rainfall (≤ 300 mm annually), high evapo-transpiration, low vegetation and undeveloped soils. Rates of wind erosion in arid to humid areas of the world are in the order of: arid > semiarid > dry sub-humid areas > humid areas. Contrasting water, wind has the capability to transport soil particles up- and down-slope and can contaminate both air and water. Wind erosion is not only disturbing the properties and the processes of eroding soils but also is severely affecting the neighboring soils and landscapes where the deposition occurs. One of the dominant sign of wind erosion is the formation of sand dunes and some time these can be as high as 200 meters in deserts. Wind erosion can be classified into different types based on movement of soil particles.

2.2.10 Suspension: The fine particles that are pushed upward into the atmosphere by strong wind and moved parallel to the soil surface have size of 0.1mm. This is exceptional erosion process because of which the fine soil particles can be conveyed high into the atmosphere and settle down again when the wind speed diminishes or brought around precipitation. The suspended fine particles can move to the hundreds of miles by wind.

2.2.11 Saltation: Soil particles dislodged with every impact and these moves along the surface of the ground by a series of short bounces. Some bouncing particles remain within 30 cm of ground surface mostly have the size of 0.1-0.5 mm. the 50 to 90% of the total soil movement by wind is accounted for this process that depend on the wind movement.

2.2.12 Soil creep: The soil particles along the surface of ground roll and slide. The bouncing effect of saltation particles is responsible for the movement of these particles. The total soil movement by wind is accounted 5 to 25% and soil creep having size of 0.5 to 1 mm in diameter can move comparatively large particles.

2.3 CAUSES OF SOIL EROSION

Soil erosion is influenced by political, economic, social conditions, climate, land use and management and topography. Poverty level directly relates with soil erosion in developing countries. There is no way to measure conservation practices for poor farmers that have limited or lacked resources. The risk of soil erosion is decreased by

implementing conservation practices. However, food production on small agriculture farms (0.5-2 ha) year after year, compels farmers to use over exploiting practices.

2.3.1 Deforestation: Energy fluxes, erosion control, moderation of climate and ecosystem stabilization are the essential ecosystem services provided by forest. Medications, wood, numerous other wood-based items and sustenance is also provided by wood.

The major causes of denudation are urbanization, unnecessary logging and clear-cutting, construction of roads and highways, frequent fires and expansion of farming to marginal lands. As the human population continues to increase, there is a clear need for more food. In addition, the increases demand of agricultural products has created incentives to convert forests to farmland and pastures.

Once a forest is converted to agriculture, many of the plants and animals that once lived there, would have usually gone forever, along with forest cover. The land availability for agriculture or other uses is done by deforestation that causes the permanent destruction of forests. The land is swept into river by erosion without vegetative cover. So, the cycle of soil loss continues by the movement of farmers in the forest, clearing more forest as well as soil fertility is also lost.

2.3.2 Intensive cultivation: Industrial agriculture that is also termed by the intensive farming or cultivation is attributed by maximum use of inputs such as low fallow ratio, labor and capital per unit land. Higher yields are produced with the use of less land and less labor that capable the farmer by more intensive agriculture. But, blessing is not unmixed for the agriculture intensification.

Human health and farm productivity is affected by increased environmental impacts by the potential degradation of water and soil resources. Even when there is not excessive soil erosion, soil quality can also be reduced by depletion in organic matter and natural supplies of trace elements as the result of intensive cropping. Wide range of plant and animal species maintain the fertility of soil with the diverse contributions and recycling of nutrients in natural ecosystem. When no fertilizers are used then some trace elements are depleted as a result of no diversity and rotation is replaced year after year by a single species grown. The organic content of the soil also decreased if there is no replacement of consumed nutrient over time when no crop residues or organic matter is added.

2.3.3 Overgrazing: In many livestock farms, the same piece of land for a long time is mostly concentrated by the herds of cattle and sheep. Soil displacement during traffic, repeated crushing or trampling and overgrazing is resulted by this confinement. Soil erosion on steeps slope or hillsides is increased when the protective cover is reduced by removing or thinning of grasses.

Acceleration of water and wind erosion, degradation of soil structure and reduction in organic matter content of soil is resulted by overgrazing.

Reduction in root proliferation and growth, soil compaction, drainage and water infiltration rate decreases by cattle trampling. Soil erosion in heavily grazing areas increases runoff by increasing stocking rate. Soil erosion is increased in wet and clayey

soils by surface runoff and compaction on overgrazing lands. Siltation and sediment-related pollution of downstream water bodies also increase due to the soil erosion of pasture lands.

As animal movement/ traffic on grazing lands could disintegrate the soil particles, soil is susceptible to erosion from these lands). Flowing water and wind can easily remove the detached fine particles of surface sand. Loss of top soil and nutrients from by the conversion of natural ecosystem that caused higher rates of erosion by increasing continuous grazing that initially damage the land. Wind and rain detach the soil particles from its original place. Inappropriate land use and other practices (overgrazing, commercial agriculture, deforestation/ removal of green cover; reduction of root stock; compaction of soils) facilitate the transportation of these detached soil particles along with wind and rain. This leads to severe soil erosion and loss of nutrients/ microbes within soils.

2.3.4 Cultivation of steep slopes: Raindrop is absorbed into soil pore spaces as it falls on the soil. When all the pore spaces are filled with water soil becomes saturated and extra water will either stand on surface or flow down as runoff. The moving water will take soil particles away and starts the process of erosion. As the intensity of rain increases, the runoff increases and the force exerted on soil particles also increases. As the slope steepness increases, the velocity of runoff and force on soil particles also increases. The soils which have less or no vegetation on the surface are more vulnerable to erosion caused by flowing water. Amount of rainfall, slope steepness, vegetation and soil type are the major factors causing slope erosion. Terracing on the slopes decreases the erosion by decreasing speed of runoff and crops which require heavy irrigation i.e. rice can be grown on these terraces.

2.3.5 Soil mismanagement: The common cause of soil erosion is the expansion of agriculture on poor quality lands; excessive irrigation, indiscriminate chemical input, and no vegetation. Crop residues are removed for fodder, bio-fuel and industrial uses. This practice leaves the soil bare from protective cover below a critical level and soil becomes vulnerable to erosion. Runoff is increased by intensive cultivation causing soil erosion, and ultimately transporting nutrients and pesticides off-site and water and soil quality is reduced. While an eroded soil is left fallow to recover, new land is brought into cultivation. Because of this, the erosion problem is worsened as during fallow period amount of dense vegetative cover is reduced.

2.3.6 Urbanization: There is significant effect of urbanization because most of the productive agricultural land near cities has been converted into residential and commercial area. As a result, agricultural area is decreasing which ultimately affects the farmer's income as the natural resources are also decreased. Despite decrease in agricultural land, the limited land is used intensively for cultivation which results in decreased soil fertility over the time.

2.4 FACTORS DETERMINING SOIL EROSION

Shear stress of runoff water and the critical shear stress of soil are the two major factors affecting gully erosion. Soil materials from the base and sides of channels by the shear stress of runoff are removed and transported to the small channels. Some of the important factors affecting soil erodibility are:

2.4.1 Slope: Slope is the major factor to control soil erosion. Length and steepness of slope are the main factors that affect soil erosion. As the steepness increases the erosion increases similarly, as the length of slope increases the eroded effect of running water increases. The water conservation practices such as terraces and buffer strips reduce the intensity of flowing water by reducing the slope. Runoff velocity of water and discharge is more from channels that have relatively more smooth surfaces. On the other hand, construction of water catchments and minimizing the soil slope reduces water runoff and thus decrease the erosion.

2.4.2 Soil structure: The arrangement or aggregation of soil particles is termed as soil structure. Intensive cultivation and large compaction results in deterioration of soil structure and particles binding and thus make them susceptible to erosion. The Soil structure results from asymmetrical and symmetrical arrangements of soil particles which keep pore spaces, micro, macro-organisms different sized aggregates, shapes and stability within a limit. The resilience of soil to erosion is largely depends upon its structure. The soils with poor structure more are weakly aggregated easily compacted and have high runoff with low infiltration. The quantitative measurement of soil structure is difficult, therefore water infiltration, air permeability, and soil organic matter dynamics are usually related to soil structure development. Measurement of properties of aggregate is also a helpful way if soil structural stability at the aggregate level determines the macro scale structural attributes of the whole soil to withstand erosion.

There are numerous techniques for characterization and modeling of soil structure. Advanced techniques for soil structure modeling aim to capture the heterogeneity of soil structure and correlate these quantifications with various processes such as erosion.

The focus on soil-based techniques, coupled with the characterization of aggregates, can provide additional insight into soil structure dynamics. Current technologies include tomography, neural networks and fractals. Tomography allows the investigation of soil interior architectural design and allows for three-dimensional visualization of soil structures. By using this method, the geometry and distribution of macro pores and micro porous networks in the soil can be examined, which facilitates the flow of air and water. The use of neural networks is another way to observe the structural properties of the soil to conserve water, store organic matter and resist erosion.

Soil debris and its sensitivity to soil erosion are controlled by fractal theory in the process of cultivation. This theory involves the study of the complexity of soil particle arrangement, tortuosity and soil pore abundance, which is the key to explain the process

of water flow through the soil. These relatively new technologies can help quantify the structural properties of the soil.

2.4.3 Organic matter: The cementing agent that binds the soil particles together is the organic matter. Organic matter plays important role in soil erosion prevention. The fundamental source of energy for soil organisms is organic matter. It is both of animal and plant origin. Soil protection from compaction and erosion, improvement in soil structure, water and nutrient holding capacity increases and healthy communities of soil organisms are supported with the frequent addition of organic matter. Crop rotations that contains high plants residues, leaving crop residues in the field growing cover crops, using low or no tillage systems, mulching, growing perennial forage crops, using optimum nutrient and water management strategies for healthy plants production with large number of residues and roots, growing cover crops and applying compost or manure are the practices that increase organic matter addition in soils.

2.4.4 Vegetation cover: Loss of protective vegetation through fire, ploughing and overgrazing makes soil susceptible to erosion by water and wind. To reduce erosion losses, the vegetative cover provides natural measure. The water is slowed down by the plants as it flows over the land and ground is soaked by allowing much of the rain to do this. Soil is prevented from being swept or blown away by the plant roots that hold the soil in place. Soil's ability to erode is reduced by plants that protect the soil from the abrasive effect of raindrops. The flow of water is slowed down by the plants in wetland and on the banks of river. The roots prevent erosion by binding the soil.

2.4.5 Land use: The best soil protector against soil erosion is grass due to its highly dense cover. The considerable obstruction to surface wash is small grains such as wheat. During the early stages of growth, little cover is provided by the row crops such as potatoes, maize that also encourages erosion. The areas that are most subjected to erosion are fallow lands.

2.5 SOIL EROSION PREDICTION

Soil losses from cultivated fields by sheet and rill erosion are predicting by Universal soil loss equation (USLE) developed by Wischmeir and Smith (1978). USLE considers all the variables as the soil erosion is influenced by several factors. Erosion losses are reduced to permissible limits by using soil management practices that are understood by combination of variables/ information related to the variables of USLE equation. In Europe and USA, this equation was successfully applied and validated in various fields. The equation is as follows: $A=R\times K\times LS\times C\times P$

Where

A = soil loss in metric tons per hectare (t ha-1)

R = rainfall and runoff factor or rainfall erosivity (j ha-1)

LS = Slope length and steepness factor (compared to reference values of 22.6 m and 9%), dimensionless.

C = Crop management factor – a ratio which compares soil loss from an experimental field with that from a field with standard treatment, dimensionless.
The soil loss in t ha-1 is obtained by multiplying all the variables.

2.6 ENVIRONMENTAL AND AGRICULTURAL CONSEQUENCES OF SOIL EROSION

The valuable top soil is the most productive part of soil profile for agricultural purposes. This is removed by soil erosion. Production cost will be high and yield will decrease by the loss of this top soil. Gullies and rills make the cultivation of paddocks impossible and these are produced by the erosion when the top soil is removed.

The long-term impacts of erosion on cropping lands include:
- Top soil that is rich in organic matter and nutrients is removed
- The depth of soil that is available for water storage for crop growth and for rooting is reduced.
- Increase runoff by reducing the infiltration of water into soil.

Short-term loss and increased costs can result from:
- Seedlings, fertilizers and pesticides, need to repeat field operations and loss of seeds.
- Erosion of soil from the roots
- Wind erosion blasted the young plants with sand
- Extra cultivations are needed to level out the eroded surfaces

Damage to the off-farm environment includes*:*
- Sediment deposition onto roads, in roadside drains and on neighboring properties.
- Excess inputs of phosphorus, pesticides and nitrogen damage the quality of lakes, coastal water and watercourses. Spawning grounds of fish damage by sediments in rivers.
- Greater flood hazard downstream is caused by the deposition of sediment and increased runoff.

2.7 SOIL AND WATER CONSERVATION MEASURES

2.7.1 Soil Conservation measures: The unscrupulous exploitation of earth's natural resources has posed a threat to sustainability. The priority concern in our country is to ensure that our dwindling natural resources are conserved today and preserved for posterity. Human existence demands this intervention. Water is the most critical input for agriculture. Sixty per cent of our farms are rain-fed. Stress is now given for management of valuable resource trinity of soil, water and biomass through conceptualization of various soil and water conservation programmes. This also promotes *in situ* conservation and harvesting of rainwater for augmenting surface and ground water resources.

The suitability of a soil conservation treatment depend on slope, rainfall (amount and distribution), soil type and depth, water holding capacity, location of impervious layer, agricultural practices, land use/land cover, and economics.

2.7.2 Arable Land Treatment Measures: Soil and water conservation measures in arable land like earthen bunds, stone pitched contour bunds, vegetative hedges, contour /staggered trenches, moisture conservation pits, etc. to intercept rainfall where it falls and to obviate the chances of the runoff water from acquiring erosive velocities in arable land.

Earthen Bunds: Bunds are small embankment type structures made up of locally available earth materials. Land slope and soil characteristics are considered for selection of bund type and design. Bunds help to check the velocity of the run-off, to carry excessive rainfall safely downstream and to let off stream flow in natural channels. Bunding increases the time of concentration of rainwater where it fall thereby allowing rainwater to percolate into the soil. Where ever possible agronomic conservation measures like agrostology, planting of grass specials etc are provided on the constructed bunds.

Fig 3 Earthen bunds

b. Stone Pitched contour bunds: Stone Pitched contour bunds are constructed in contour at suitable intervals in slopes. The adoption of this intervention has led to reduction in soil erosion and increased water availability for crop plants. This type of construction is very suitable for laterite soil or wherever stone is available, up to 35% of slope areas can be protected by this way.

Fig 4. **Stone Pitched contour bunds**

c. Graded bunds: Graded bunds are adopted in areas having low infiltration (< 8 mm/hr) and more than 800 mm rainfall. Graded bunds are laid along pre-determined longitudinal grade instead of along the contours for safe disposal of excess runoff. Gradient given may vary from 0.4 to 0.8%. (0.4 for light soils and 0.8 for heavy soils).

d. Vegetative Hedges: Runoff velocity can be reduced drastically by planting vegetative hedges, bunch grass, or shrubs on the contour at regular intervals .These hedges can increase the time for water to infiltrate into the soil and facilitate sedimentation and deposition of eroded material by reducing the carrying capacity of the over land flow. Vegetative hedges or narrow grass strips serve as porous filters. These hedges may not reduce runoff amount but can drastically decrease soil loss.

e. Trenches: Contour trenches are used both on hill slopes as well as on degraded and barren waste lands for soil and moisture conservation and afforestation purposes. The trenches break the slope and reduce the velocity of surface runoff. It can be used in all slopes irrespective of rainfall conditions (i.e., in both high and low rainfall conditions), varying soil types and depths.

f. Contour trench: Trenches are constructed as continuous across slope with 45-50 cm depth and bottom width and trapezoidal in shape. A contour trench is made on contour lines. Contour trenches are constructed on the ridge part of the watershed where the slope is between 10- 25%. Since the trench is on the contour line, water within the trench does not flow from a higher to a lower level. Water is retained there. Trenches help to reduce the flow of run-off. They retain and break the velocity of water. Plantation of trees and sowing of seeds of grasses may also be undertaken on the excavated soil which is supported by extracted boulders so that soil does not get washed out during rains.

Fig 5 Contour trench

The distance between two rows of contour trenches ranges from 10 meter to 30 meters depending on the rainfall, the slope, the vegetation and the soil type. Contour trenches are broadly of three types viz. Contour Trenches, staggered contour trenches and continuous contour trenches.

Steps for Construction of Contour Trenches

Step 1: Measure the slope of the ridge area. If the slope is between 10% and 25%, contour trenches may be constructed.

Step 2: Determine the distance between two rows of contour. It may range from 10 to 30 meters. The higher the slope the less the distance and vice versa.

Step 3: On these rows, use A-frame/Abney level to identify contour lines.

Step 4: Dig trenches on contour. Place soil on the downward side of the trench placing pebbles and stones so that soil does not flow away. Keep some distance between trench and soil.

Step 5: Plant trees of fast growing and of fodder native species on the excavated soil.

g. Staggered trench: The length of trenches is kept short up to 2-3 m and are spacing is 5-7m. It is suited for medium rainfall areas with dissected topography.

h. Water Absorption Trench (WAT): A Water Absorption Trench (WAT) saves downstream treatment from the intense storm. A WAT should be strictly taken along contours. Rows or lines of WATs shall be taken on non- uniform slopping land. Extra runoff is diverted into natural gullies. The maximum size of a WAT is 1 x 1 mt.

i. Strip Terrace:

It is used to control soil erosion in highly sloped areas. It basically involves construction of ridges and step like structures across land slope. Strip terrace are commonly adopted in area of rubber plantations in Kerala.

Fig 6 Strip Terrace

j. Moisture Conservation Pits:

Any form of depression or micro pit is constructed over the land surface to arrest excess surface runoff and silting and thus leading to ground water recharge.

Fig 7. Moisture Conservation Pit

Pits of suitable dimension are constructed in the field which would impound water and contribute o ground water recharge during rainy season. The silt accumulated in the pits could be dug out and used in the farmer's field which would improve nutrient status of the soil.

k. Contour Bunds: Contour bunds are made on the ridge area where the slope is less than 10%. Soil bunds are erected on contour lines to reduce the velocity of the water flowing down the hill. Contour bunds should not be constructed very closely. The distance would vary with rainfall, vegetation, soil and slope. However, a distance ranging from 30-60 meters may be kept between two rows of contour bunds.

How to construct contour bunds?

The following technical details should be followed while constructing contour bunds:

- The height of the bund should vary from 50-60 cms. Soil settles after the rains, therefore, a provision for 25% additional height should be made.
- The top width of the bund should be between 20-30 (permeable soil) and 30-40 cms (impermeable soil).
- Upstream slope should range from 1:1 (permeable soil) to 1.5:1 (impermeable soil)
- Waste weir pitched with stone for each row of contour bund should be provided.
- Excavation should be on the upstream side of the bund
- Some distance between trench and bund should be maintained.
- Grass should be sown on bunds.
- Spacing between two contour bunds depends on the slope of the area, as well as the permeability of the soil.

l. Agrostological measures: Suitable grass species preferably fodder grass is planted in rows across the slope. It can also be planted on the berm of bunds. The fibrous root system of grass will offer better protection of the top soil and filter the run off to trap the sediments.

Fig 8. Agrostological measures

Well established grass species reduce erosion by moderating the impact of raindrops and also increases the infiltration opportunity time. The grass thus planted could be used as fodder for livestock, which could also be an alternate source of income to the farming community.

m. Agro-forestry: Agro-forestry measures proposed include planting of woody perennials (Trees, Bamboo, Shrubs etc) wherever necessary to control soil erosion. These measures reduce erosive force of water through impeding effects of tree roots and through soil cover provided by the tree canopy and litter. These are potential enough to conserve soil and moisture in the area through a combination of mulching and shading.

2.7.3 Conserving water for future use

Need for Water Conservation and Management: It is estimated that with increasing demand from other competing sectors, the availability of water for irrigation sector is likely to reduce progressively to about 75 percent in future. Irrigated agriculture which consumes the major part of the total water being used should be the focus and fore-runner for achieving maximum conservation in its use.

Even a marginal improvement in the efficiency of water use in this area will result in the saving of a large volume of water which can be utilized either for extending the irrigated area or for diverting to other beneficial purposes.

The inevitable reduction in loss in availability of total water for irrigation sector has to be offset by improvement in irrigation efficiencies. However, improvement in water application efficiencies and productivity levels alone will not be sufficient and it is an imperative to create additional potential and bring more area under irrigation.

Therefore, there is urgent need to create more storages for conserving water which is available during monsoon period only, for its use during lean period. This scenario of rising competing demands for various sectors and mismatch of water availability and demand highlights the need for conservation of water. Water conservation has three dimensions:

i. **Water resources conservation-** efficient management of available water through proper storage, equitable allocation and transfer to scarcity areas for use. Preservation of the quality of the resource including ecosystem conservation.
ii. **Water use conservation-** water supply and distribution with minimum losses and consumption through prevention of wastage.
iii. **Efficient use of water** through adoption of water saving technologies and cropping patterns.

2.7.4 Drainage line treatment: Drainage channels/gullies are the carriers of runoff and sediment in watershed. Steep bed gradient (Slope) of a channel cause high runoff velocities with associated heavy sediment flow. Hence channel gradient needs to be reduced in order to being the runoff velocities within permissible limits.

The Drainage Line treatments aim at betterment of the drainage lines and facilitate better local production environment of the concerned areas by providing the required basic infrastructure. Moderation of Floods and related damage, control of saline intrusion etc. are the major areas which facilitate increased productivity.

The Drainage Line treatments aim at betterment of the drainage lines and facilitate better local production environment of the concerned areas by providing the required basic infrastructure. Major items of works that can be taken up are given below

Interventions in the ridge area

- On slopes greater than 25%, instead of constructing structures, plant and protect grasses, shrubs and trees native to the area.

- Where boulders are available, contour bunding with boulders (without disturbing boulders embedded in the ground).
- Contour trenches on slopes between 10-25%.
- Encouraging natural regeneration by controlling grazing, fire control, coppice dressing, adoption of regenerating seedlings, treating bamboo clumps etc.

a. Loose Boulder Structures: Loose boulder structures (LBS) are constructed on small drains with depth less than 3 meters. It is one of the most common drainage line treatments. It is always made in a series starting from the top of the drainage line to the bottom in such a manner that the vertical distance between two LBS should be equal to the height of the LBS. The top of the LBS should be at the same height as the bottom point of the previous LBS and similarly, the bottom point of the LBS should be at the same height as the top of the next LBS. The distance between two LBS may vary from 10-50 meters depending upon the slope of the drain, run off rate etc.

Each LBS should be properly constructed, as damage to one may result in causing damage to other structures in the drainage line. Since construction of LBS requires a lot of loose boulders, its construction should be undertaken where loose boulders are locally available.

Dimensions

- The top width should be around 0.5 meters
- The upstream slope should be 1:1
- The downstream slope should be 1:3
- Fairly large stones should be placed at the center of the stream to resist the velocity of the run-off
- There should not be any gap between two stone joints. If any gap is there, it should be filled with small stones

b. Gully plugs:

Gully plugs are built using local stones, clay and bushes across small gullies and streams running down the hill slopes carrying drainage to tiny catchments during rainy season. The sites for gully plugs may be chosen whenever there is a local break in slope to permit accumulation of adequate water behind the bunds.

Fig 9. Gully Plugs

2.7.5 Rain water harvesting through Check Dams / Cement Plugs/ Nullah Bunds:

Check dams are constructed across the stream flow to reduce the velocity of runoff water and to entrap the sediments. The site selected should have sufficient thickness of permeable bed of weathered formation to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to stream course and the height is normally less than two meters and excess water is allowed to flow over the wall. In order to avoid sourcing from excess run off, water cushions are provided at downstream side.

Check dams are built in a range of sizes using a variety of materials, including clay, stone and cement. Earthen check dams, or embankments, can easily be constructed by the farmers themselves. There are logwood Check Dams, loose boulder Check Dams, dry rubble check Dams and Concrete/ masonry check Dams. Masonry and reinforced cement concrete (RCC) check Dams are of more permanent in nature and serve the purpose of water conservation. The sluice, spillways and other regulatory structures constructed in the drains help to regulate the flow of excess water.

Loose boulder check dam is constructed using locally available stones and other materials across the stream to reduce runoff velocity and to entrap the sediments. Masonry check dams are constructed across streams of heavy flow and high velocity. The construction cost is usually high and requires hydrologic and hydraulic designs. Gabion check dams are very much suitable for degraded locations like high rainfall areas with torrential streams/drainage lines to stabilize.

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Fig 10. Check dams

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Gabion check dams are very much suitable for degraded locations like high rainfall areas with torrential streams/drainage lines to stabilize.

b. Percolation Tank: Percolation tanks are small water harvesting structures constructed across natural stream or water course to artificially recharge ground water during lean months. These structures increase the availability of water in the wells of surrounding area even during dry spells, which can be utilized by farmers for domestic as well as for irrigation purposes. They are constructed across nalas for checking velocity of run off for increasing water percolation, improving soil moisture and promote siltation.

Fig 11 Percolation Tank

Pineapple or guinea grass could be planted on the berm of the pond which will apart from providing better reinforcement; provide additional income by way of fodder /fruit. During the dry seasons, the ponds could be put to alternate use by dumping organic wastes which can be used as manure before the onset of monsoon.

c. Gabion Structure: A gabion is a rectangular shaped cage made of galvanized wire, which is filled with locally available boulders, rocks and stones. The gabions are conveyed flat to the location and are folded there. The Gabion check dams are constructed by connecting several gabions. They are constructed in drains where the sediment load is high.

Fig 12 Gabion Structure

A Gabion structure is one of the low cost structures constructed across small streams to conserve stream flows with practically no submergence beyond stream course. A small bund across the stream is made by putting locally available boulders in a mesh of steel wires and anchored to the stream bank. The height of such structures is around 0.5 meter and is normally used in the streams with width of less than 10 meters. Stabilizes the drain and helps in ground water recharge.

d. Stream Bank Stabilization: Due to undulating topography and high intensity of rainfall, huge quantities of rainwater flow through the drains. The existing drains are silted and flow of water through the drains is restricted resulting in severe bank erosion, overflow and spreading of water through adjacent agricultural land causing damage to crops. Stream bank stabilization is done by constructing retaining walls of different configurations and design. By stabilizing the stream banks, the flow can be regulated, scouring of banks avoided and drainage congestion can be averted.

Fig 13 Stream Bank Stabilization

e. Coir Geo textiles: Coir geo-textiles is used as an erosion control measures for lake, canal and river bank protection. Coir mesh–mattings are used extensively in erosion control works. The ultimate objective is to establish a dense network of root system and vegetative cover to the desired degree of growth in the shortest possible time. Coir geo textiles intercept rainfall and aid in In situ moisture conservation.

Fig 14 Coir Geo textiles

f. Vanrai Bund: Vanrai Bunds are constructed to arrest runoff and flow of water post monsoons. At suitable places in streams a shallow trench is excavated across the nullah and a clay filled cement bags arranged as a wall are also being successfully used as a barrier to prevent runoff.

g. Spring water development/ Aquifer Protection: Springs could be artesian, gravity or seepage type. As contamination is the major threat as far as spring water source is concerned, steps should be taken to prevent contaminants from flowing to the spring source. Starting at the highest point(s) at which there is evidence of spring water issuing from the soil, excavate narrow trenches uphill following the direction from which most of the water is flowing.

Trench should be about 1.m. deep if sufficient water is flowing into the end of the trench from the 'eye' of the spring. Stone filled trenches and pipes are laid to convey water from the protected source. Required side walls, wing walls and aprons are proposed to maintain steady flow from the springs and to aid in better utilization of water. The spring thus rejuvenated is protected further by construction of diversion ditches and fences to prevent polluted surface water from flowing through the fence onto the site of the spring.

2.7.6 On-farm Interventions

a. Terracing: A terrace is an earth embankment, or a ridge and a channel constructed across the slope to intercept surface run-off and convey it to a stable outlet at a non-erosive velocity, to minimize soil erosion. This technique is very cost effective. Most of terraced land is used for rice cultivation.

Fig 15 Terracing

b. Farm Ponds: Farm ponds are small reservoirs constructed for the purpose of storing water essentially from the surface run-off. These measures are undertaken in areas where rain-fed agriculture is undertaken basically for supplemental or as protective irrigation. Two types of farm ponds are common:

(a) Dug out ponds

(b) Embankment type ponds.

In dug out ponds, soil is excavated and the excavated soil is used for embankment. Generally, these ponds are constructed in a rectangular shape and water is channeled into the pond to avoid soil erosion. Embankment is made using soil on the downward slope of the farm to retain water.

A site having a general depression is chosen for constructing embankment pond. The impounded water also provides lifesaving irrigation to the lands in the Ayacut. It will increase the soil moisture regime around the structure for increased crop production and recharge the ground water.

Fig 16 Dug out pond

Fig 17 Embankment type pond

c. Roof top Rain water Harvesting: Rain water harvesting is a technique of collection and storage of rain water at surface or in sub-surface aquifers, before it is lost as surface run-off. The augmented water resource can be used in the time of need. Artificial recharge to ground water is a process by which the ground water reservoir is augmented at rate exceeding that under natural conditions of replenishment.

Methods of Ground water Recharge through Roof top Rainwater Harvesting: Roof Top Rain water/ Strom run off harvesting through

- Recharge Pit
- Recharge Trench
- Tube well/ Bore-well recharge
- Recharge Well

d. Dug-well Recharge:

Existing and abandoned dug well may be utilized as recharge structure after cleaning and desilting. Collection of rain water from roof top of households and diverting the same to wells after proper filtration will be resorted to recharge wells.

Fig 18 Dug-well Recharge

To ensure that the water to be recharged is free from silt, the runoff is made to pass through de-silting or filter chamber. The water from the filter chamber is guided through a pipe to the bottom of well or below the water level. Periodic chlorination should be done for controlling the bacterial contamination.

2.8 AGRICULTURAL CONSERVATION MEASURES

Contour cultivation, manuring, mulching and mixed cropping are included in these practices.

2.8.1 Crop management: Soil fertility is improved and wind and water reduce soil erosion by good crop management practices. Keeping soil covered is fundamental principle of

conservation agriculture. Soil protection from erosion by leaving crop residues on soil surface after harvesting is also helpful approach.

a. **Crop selection:** If the gap is too long between harvesting one crop and sowing of the next crop than the additional cover crops may be required. The stability of the conservation agriculture system is increased by cover crops and erosion impacts are reducing by the improvement of soil properties and this biodiversity in the agro-ecosystem are promoted for their capacity. The more effective crops for preventing soil erosion are perennials than annual crops. The most effective are sugar cane, fodder grasses, sweet potatoes and tea.

b. **Early planting:** The protection of the ground against raindrop impact is ensured by the crop shoots from the ground within one or two weeks after the onset of the rains.

c. **Crop rotation:** The practice of growing a series of dissimilar types of crops in the same space in sequential seasons is crop sequencing or crop rotation for benefits such as avoiding pathogen and pest buildup that occurs when one species is continuously cropped. Soil nutrient depletion is avoided by the crop rotation that balance the nutrient demand of various crops. The replenishment of nitrogen with the use of green manure and legumes in sequence with cereals and other crops is a traditional component of crop rotation. Soil structure and fertility by alternating shallow-rooted and deep-rooted plants can also be improved by crop rotation. Growing multi-species cover crops between commercial crops is also another technique. The advantages of intensive farming with polyculture and continuous cover are combined by these techniques. So, soil fertility, reduction of diseases and pests, addition of humus and control of erosion is ensured by crop rotation.

d. **Inter-cropping:** The impact of raindrops is reduced with the soil cover by the fast-growing legumes such as cowpeas and beans early in the season before a canopy is developed by cotton or maize to shield the soil.

e. **Cover cropping:** The practice of growing crops to cover the soil surface to reduce wind and water erosion is called cover cropping. This practice creates a favorable habitat for microorganisms by regulating the soil heat and temperature. These also sources of organic matter in soil as the fallen are decomposed.

f. **Strip cropping:** This is the practice of growing different crops in alternate strips in the same field. It helps minimizing wind and water erosion. Crop rotation and minimum tillage in addition to contour strip cropping has proven to be best method to conserve soil and water.

2.8.2 Soil management: Soil conditions are often changed by the inappropriate land use practices which ultimately result in soil erosion. Optimum soil management aims to provide favuorable conditions for plant growth through improved soil nutrient availability and aggregation. Optimum soil management practices improve infiltration of water and improve soil capacity to hold water and in result reduce runoff and erosion.

a. **Use appropriate tillage practices:** Optimum soil physical conditions for better crop production are the main objectives of tillage. It also ensures timely seedbed

preparation, planting and weed control. Tillage practices should be adopted by keeping in mind that;

- Soil is neither too fine nor powdery; and
- It breaks up the hardpan if necessary.

The main tillage methods are slash and burn, hand hoeing, ploughing and harrowing, conservation or minimum tillage, deep tillage.

b. Applying organic manures and mineral fertilizers: Application of manure and fertilizers provide essential plant nutrients in the soil for better crop growth. The crops with fast growth cover the soil quickly and give higher yields. Essential plant nutrients such as nitrogen, phosphorus, potassium, and sometimes Sulphur required by plants are provided by inorganic fertilizers. There is no substitute of inorganic fertilizers therefore integrated use of organic and inorganic fertilizers should be adopted. Farmyard manure, green manure and composts etc. are the main sources of organic fertilizers.

c. Mulching and the use of crop residues: Spreading on the bare soil surface or placement of plant materials such as dry grass, straw, dry leaves, banana leaves, sugar cane trash, and other crop residues around the stem of the plants is helpful in controlling soil erosion and moisture conservation.

d. Agro-forestry: Planting of trees or shrubs or protecting the naturally sustaining trees is called agroforestry. Trees decrease the magnitude of splash erosion by reducing the raindrops impacts on the soil. They regulate soil temperature by shading the soil thus reducing the water evaporation. They also minimize the wind erosion by acting as wind breaks. They also play important role in nutrient recycling in the deep soil; leguminous trees fix nitrogen that benefits food crops.

e. Contour farming practices: Cultivation across the slope rather than up and down is called contour farming. Soil loss as much as 50% has been reported to be reduced by contour farming on gentle. The main objective of contour ridges in semi-arid areas is water harvesting. Plant residues are placed in lines along the contour for construction of trash-lines. These trash-lines slow down the runoff and trap the eroded soil. Grass barrier strips of Napier or other fodder grasses are planted along the contour.

2.9 LET'S SUM UP

Substantial development has been made in emerging conservation techniques against erosion. A better understanding of factors, processes of soil erosion, causes and the related process are being investigated by the middle of 20th century. The magnitude of soil erosion risk is determined by the better understanding of the factors that establish more effective control practices in many regions of the world. The extent of soil erosion remains high in spite of these technological advances. Soil erosion is a potential threat to environmental and agriculture sustainability and economically feasible, environmentally sound practices of soil conservation are the base of farming system. To achieve the objective of conservation of soil and water in the agriculture sector focus of attention will have to be on-augmentation and creation of additional resources, performance

improvement of existing systems, coordination amongst various agencies, provision of adequate funds for creation of additional resources and conservation measures, ensuring users' participation, giving impetus for benchmarking of irrigation system, creating mass awareness for better management of availability and demand and environment protection. Strategies will need to focus on augmentations and optimum utilization without sacrificing on quality with people's participation.

The growth of agriculture sector and rural livelihood depends on important natural resources like soil and water. High productivity goals and intergenerational food security is achieved critically by the conserving these vital natural resources. Soil and Water resource development is to be seen not merely as a single-sector-end objective, but as a prime mover in developing larger systems with multiple linkages. This calls for a well set out multi-disciplinary agenda covering not only technological issues but also issues of social, economic, legal and environmental concerns. Therefore the planning, development and management of soil and water resources has to be taken up in an integrated manner for addressing the concerns facing the soil and water sector. This integration has to be a multi-disciplinary approach which would take care of all the conflicting issues and deliver solutions that would be technically feasible, economically viable, socially acceptable and ecologically & environmentally sound. Water use, in turn, has its impact on water quality and therefore utilization of water has to be so managed as not to contribute to the deterioration of water quality that may seriously jeopardize its future availability.

2.10 CHECK YOUR PROGRESS

1. State different types of soil and water erosion?
2. What are the different causes of soil erosion?
3. Describe various measures for soil and water conversation?
4. How to predict soil erosion
5. What are the different environmental and agricultural consequences of soil erosion?
6. What are the different agricultural conservation measures?

2.11 FURTHER READINGS/ REFERENCES

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UNIT 3: FARMING SYSTEMS FOR SUSTAINABLE AGRICULTURE

Highlights of the Unit

- Objectives
- Introduction
- Natural farming
- Organic farming
- Mixed farming
- Commercial farming
- Precision farming
- Integrated farming system (IFS), Concept, Objectives, Elements, Components
- Let us sum up
- Check Your Progress
- Further Reading/ reference

3.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Different farming system
- Concept of Integrated farming system (IFS)
- Why Integrated Farming System is needed
- Elements of Integrated Farming System
- Factors Determining Type of Integrated Farming System

3.1 INTRODUCTION

Sustainable Agriculture involves practices and methods which meets changing food and forage needs of man and his livestock respectively with due protection of natural resources (soil, water and environment). Methods should be economically viable, environmentally sound and protect public health. It does not only concentrate on natural resources aspect of farming, but also on the economic aspect of farm produced and market purchased inputs use in the processes thoughtfully and effectively. These contribute to the growth of nutritious and healthy food to the changing needs of man and his livestock as well as bring up the standard of living of the farmer

There is no status quo and Agriculture is never static system. It has been said farmers are the first land stewards and agricultural scientists are their mentors, guides and philosophers. Research and dissemination on weather, soil, crop, society and economic aspects led to gradual shift in optimal practices and farming systems from time to time. Let us examine various farming systems and how they meet Sustainable Agriculture requirements.

3.2 NATURAL FARMING

Natural farming philosophy is working with nature to produce healthy food to keep ourselves healthy and to keep the land and environment healthy. Everything in Nature is useful and serves a purpose in the web of life. Also termed 'Do Nothing Farming', because the farmer is considered only to be a facilitator - the real work is done by nature herself. No tillage and farming without the application of inorganic fertilizers, herbicides and pesticides. Here actual physical work and labor has been seen to reduce by up to 80% compared to other farming systems. Fukuoka started Natural farming in Japan, by experimenting with the nature and following the natural ways of crop propagation and development.

The essence of natural farming is minimizing the external inputs to the farm land, which degenerate the soil nature. At first, because there was no habitat for many of the insects, he had to make natural insecticide like pyrethrum which comes from chrysanthemum roots, and he had to spray that on his vegetables in order to keep pests like cabbage worm and cabbage moths away. When we follow nature without destruction, nature takes care of us. Zero- Budget Natural Farming (ZBNF) is proposed by Mr. Subash Palekar, in India, with the same philosophy but with the indigenous supplements In ZBNF, soil is supplemented with the microbial inoculums like Beejamrutham and Jeevamrutham to accelerate the propagation of soil micro flora, beneficial to soil enrichment. Indigenous pesticide decoctions of leaves with cow urine Neemastram and Bramhastram etc., are introduced. The philosophy of the natural farming is to nurture the growth of these beneficial microorganisms without using external manure and chemical pesticides.

In a natural farming the population of the desired crop is decreased and associated crops are included increasing the biodiversity to control pests and diseases and to improve fertility. Smaller quantities of a greater variety of goods/products are produced. Thus, the total productivity is increased. Whole crop is not harvested, in order to let the nature breed the beneficial insects, by the left out material of fruits/seeds/remnants on the field. These fruits/seeds/remnants attract other beneficial birds and insects, which increases the biodiversity and sustains original ecosystem. The role of the farmer is only to help the nature flourish.

3.3 ORGANIC FARMING

Organic farming is a method of crop and livestock production that involves much more than choosing not to use chemical fertilizers, pesticides, genetically modified organisms, antibiotics and growth hormones, provide attentive care that promotes the health and meets the behavioral needs of livestock. It relies on ecologically balanced agricultural principles like tillage, crop rotation, green manure, organic waste, biological pest control, mineral and rock additives.

Organic farming make use of pesticides and fertilizers if they are considered natural and avoids the use of various petrochemical fertilizers and pesticides. Finally, organic farming is based on various laws and certification programs of certification agency, which prohibits the use of all synthetic inputs and health of soil and environment are regarded as theme of the method. Both natural and organic farming's are environmentally sound and protect public health, but cannot meet growing population and changing food and forage needs of man and his livestock respectively.

3.4 MIXED FARMING

Also called Farming system represents an appropriate combination of farm enterprises (cropping systems horticulture, livestock, fishery, forestry, poultry etc.) and the means available to the farmer to raise them for profitability. It interacts adequately with environment without dislocating the ecological and socioeconomic balance on one hand and attempts to meet the national goals on the other. Mixed farming refers to subsistence level of farming whereas farming system refers to profit making level.

Simple example of mixed farming is Livestock- cereal cropping, where whole straw and some grain of cropping used as forage and feed for livestock and dung and urine from livestock used as fertilizer for crop at subsistence level and balance supplemented with chemical fertilizers in farming system.

Other examples of mixed farming are Aquaponics where the fish wastes are useful as fertilizers for the vegetables (like lettuce) and the lettuce, in turn, clean the water for the fish. Another similar setup and benefit is rice-fish farming in northeast, Thailand and China where fish (like tilapia and carp) are bred in the rice field water.

Mixed farming or farming system meets all requirements of sustainable agriculture needs but at very minuscule level cannot meet whole Waste management (Re-using) by-products of enterprises and Sustainability of environment/ecosystem.

3.5 COMMERCIAL FARMING

Commercial farming is a type of farming in which crops are grown for commercial use only by modernized method of farming using advanced technological means for sale in the market. In this type of farming large tracts of lands, sophisticated heavy machinery and skilled labour are used. With recommended practices required quantity and quality of reasonably priced food and feed available to man and his livestock. But under intensive commercial farming with more than recommended dose of chemical fertilizers and pesticides, natural ecosystems are disrupted or destroyed. Species are endangered by this destruction. Monoculture invites widespread disease of crops or livestock. Nearly every farmed plant or animal has been adapted to depend on human intervention to prosper.

3.6 PRECISION FARMING

Precision agriculture (PA) is an approach to farm management that uses information technology (IT) to ensure that the crops and soil receive exactly what they need for optimum health and productivity. PA is also known as satellite agriculture, as-needed farming and site-specific crop management (SSCM).

All aspects of the environment – soil, weather, vegetation, water – vary from place to place. All these factors determine crop growth and farming success. Precision farming is about managing all these variations in the field accurately use only required quantities of input resources and reducing production costs and sustaining same productivity.

Precision agriculture is one of many modern farming practices that make production more efficient. Growers are able to take large fields and manage them as though they are a group of small plots. This reduces the imbalanced and wrong dosage of inputs, their time, method of application and increases crop and farm efficiency. Crop production based on weather patterns, soil temperature and humidity, growth, and other factors is being followed by farmers. Crops are rotated to improve diversity, and irrigation rates are monitored so that salts do not accumulate.

Precision agriculture would entail the farmers to apply nutrients, water, seed, and other agricultural inputs in required rates and time. The inputs are saved and could be used on more area or more crops could be raised in a wide range of soil environments .Further ecosystem and environment is also protected. The limitations are that it is not cost effective and in only in fancy stage.

3.7 INTEGRATED FARMING SYSTEM (IFS)

It is a system which comprises of inter-related set of enterprises (livestock, fish etc.) with crop activity as base, which provide ways to recycle products and "waste" from one component as input for another component of the system, reducing cost of cultivation and improving production/income sustaining inherent characters of natural resources."

As such both approaches of mixed farming/farming system and integrated farming are based on resource planning, integration of agricultural enterprises, cyclic processes; maximization of per unit farm income and individual/social involvement, but the differences comes from very minuscule points of full utilization of by products (waste management) and sustainability of environment/ecosystem.

After attaining independence, our country has got ability to produce 5 times more food grains, 9 times horticultural crops, 9.5 times milk production and 12 times fish production per annum as seen in terms of maintaining more than 60 million tones buffer stock for any uncertainty and emergency. Yet FAO states that 194.6 million people accounting a quarter of the undernourished population in the world are from India.

The Indian economy is predominantly rural and agrarian, and the declining trend in size of land holding from 0.5ha in 1950-51 to 0.15ha by the turn of the century community

poses a serious challenge to the sustainability and profitability of farming. Cultivation of cereals, pulses alone in diminished farm size neither providing sufficient employment nor remunerative family income and 40% of the farmers opted out to leave agriculture, if they be given other jobs. Further the by products produced in some cropping systems cannot be recycled and being burnt (especially paddy straw in North West India) causing pollution problems. In this regard, Integrated Farming systems(IFS), is a valuable approach in addressing the above problems and to attain sustainable economic growth prevent farmer migration and further meets all goals of sustainable agriculture. Hence, it is necessary to study the integrated farming system in detail.

3.7.1 CONCEPT

An arrangement of recycling of products/by products/ waste /refuse of one component (enterprise) as input fed to another linked component offers profuse employment, regular production and income besides reducing production risks, cost of cultivation through optimal use of natural resources and internal resource recycling by effective utilization of family labor.

3.7.2 Why Integrated Farming System is needed

1. Reducing risks due to biotic and abiotic stresses
2. Reducing high input cost for meeting rising demand in food, feed and fiber
3. To meet increased nutritional requirements of the family.
4. To meet increased demands of soil nutrients
5. To increase income of the farmers
6. To meet increase demand in employment, standard of living and sustainability

3.7.3 Objectives of Integrated Farming System

1. To identify existing farming systems in specific areas and access their relative viability
2. To formulate IFS models involving main and allied enterprises of different farming situations.
3. To ensure optimum utilization of and conservation of available resources and effective recycling of farm residues within the system
4. To maintain sustainable production systems without damaging resources and environment
5. To rise overall profitability of farm house hold by complementing main/allied enterprises with each other.
6. To integrate different production systems like dairy, poultry, livestock, fisheries, horticulture, sericulture, apiculture etc. with agriculture production crops as base.
7. To increase farm resource efficiency (land, labor, production/by products) so as to increase farm income and gainful employment
8. To promote multiple cropping(out of total cultivated area only 18% sown more than once) for multi-layered crops of economic values so as to sustain land productivity

9. Preserving and enhancing natural soil fertility conditions through favorable crop rotations, mixed cropping, green manuring, green leaf manuring, vermicomposting etc.
10. To promote natural eco-system services like natural pest control, pollination by providing diverse natural covers(plants and shrubs) on the farm household
11. Consequently reduce and rationalize use of purchased chemical inputs (fertilizers and pesticides) to provide healthy produce and by-products.
12. To utilize new innovation of cluster approach and market linkage as diverse products from different enterprises cannot be sold in local markets.
13. To maintain and improve diverse environment on the farmhouse hold premises through landscape and nature conservation practices.
14. To pay attention to detail continuous improvements and managing all resources and fulfill social requirements
15. For pollution control and to maintain environmental quality and ecological stability.
16. To establish off farm enterprises to process, store and refine products and by-products produced on the farm house hold.
17. To arrest exodus of farmers to urban areas quitting farming and involve youth who are intuitionist in operating smart phones and ICT tools to be attracted in ease doing cluster approach, market linkage and realizing premium price to diverse and new products produced on the farm.

3.7.4 Elements of Integrated Farming System

1. Watershed,
2. Farm Pond,
3. Bio-pesticides,
4. Bio-fertilizers,
5. Biogas,
6. Solar energy utilization units,
7. Vermicomposting units,
8. Livestock and allied units,
9. Green leaf manuring plants,
10. Agroforestry units,
11. Rain water harvesting units.

3.7.5 Factors determining type of Integrated Farming System

a. **Physical Factors:** Climate, soil and topography
b. **Economic Factors:** Marketing, cost, labour availability, capital, land value and consumer demand.
c. **Social factors:** Type of community, Transport available and marketing facilities
d. **Objectives:** Expected income, production, minimizing cost and output products desired
e. **Environment:** Availability of resources, components and their suitability
f. **Prevalence of pests**, diseases, weeds and their control

g. **Prevalence of problems** of wild boar, monkeys etc.

3.7.6 Main components of Integrated Farming System

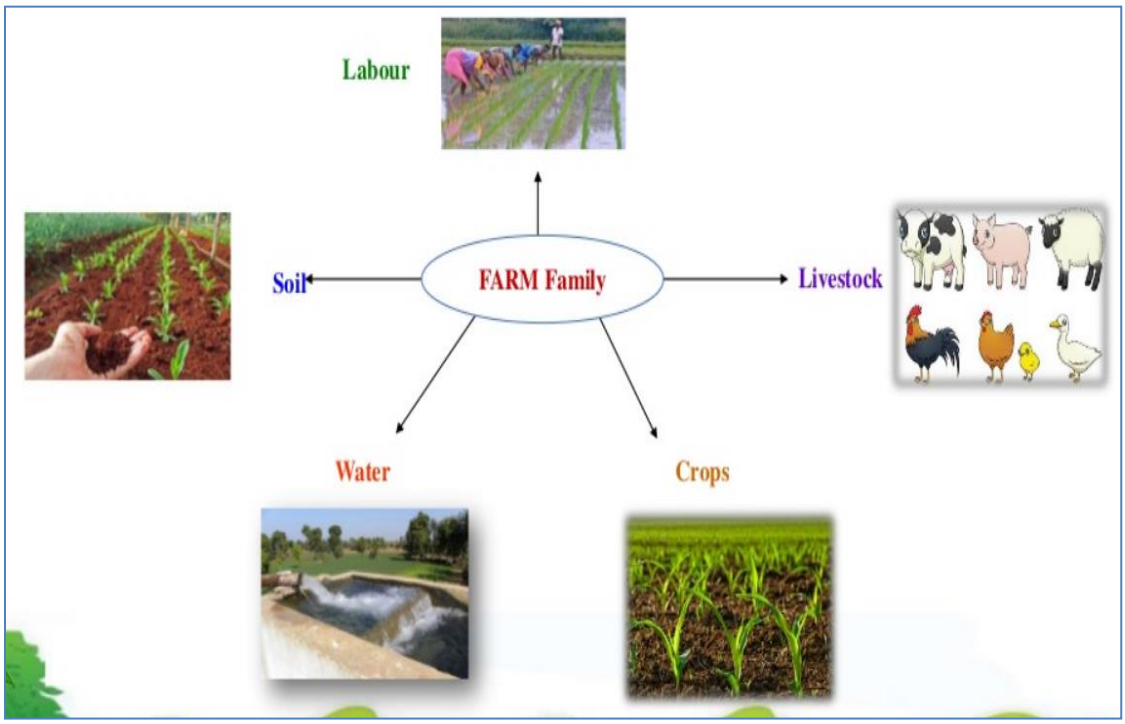

Fig 1 Major components of Integrated Farming System

3.7.7 Allied components

1. Crop Husbandry
2. Horticulture
3. Agro-forestry units
4. Livestock-cattle, Sheep, goat, poultry, duckery, piggery and quails
5. Aquaculture
6. Apiculture
7. Sericulture
8. Mushroom cultivation
9. Biogas plant

3.7.8 Integrated Farming System for different ecosystems

a. Irrigated low and uplands
b. Rain-fed and dry land areas
c. Hill Regions

3.7.9 Popular Enterprises linked to different Agro-Eco systems

Dry land	Garden land	Wet land
Dairy	Dairy	Dairy
Poultry	Poultry	Poultry
Goat + Sheep	Mushroom	Mushroom
Agroforestry	Apiary	Apiary
Farm pond	Piggery	Fishery
Grass and fodder trees + lamb rearing	Sericulture	Duckery

3.7.10 Successful irrigated upland Integrated Farming System model of Tamil Nadu (Annamalai Centre)

Crop component	Livestock component
Sun Flower – maize + Cowpea – Green gram	Cross bred milk Cows
Fodder Crops – B N Grass + Desmanthes (hedge Lucerne)	Tellichery Goats
Bhendi – Chillies – Bhendi	Guinea Fowls

3.7.11 Successful Integrated Farming System Models of ICAR Institutes

a) Crop poultry – Fishery Integrated Farming Systems – Annamalai University

Crop - Rice
Livestock - Poultry
Fish - Local

b) Crop Horti – Livestock – Fishery Integrated Farming Systems Model- ICAR North East Hill Zone (NEH) Mizoram Centre

Crop - Up Land Paddy
Maize
Horticulture - Leechi
Guava
Papaya
Livestock - Dairy Cattle
Pig
Poultry
Duck
Rabbit
Fish - Rohu
Catla
Mrigal

c) Crop Dairy – Silvi-pastoral System - Integrated Farming Systems Model- ICAR NEH Mizoram Centre

Crop - Maize,Soya Bean
Horticulture - Banana
Silvi Plants - Teak
Pastoral - Congo signal
Setaria, Guinea Grass

3.7.12 Productivity and Economic Analysis of successful Integrated Farming System Model.

Integrated Farming System	Net Returns (Rs/ ha)	Per Day Returns (Rs/ ha)	Duration of the system (Days)	Employment Generation (Days)
Cropping alone	36,190	167	369	369
Crop + Poultry + Fish	1,14,665	436	420 (369+ 51)	515
Crop + Fish + Pigeon	1,18,462	443	420 (369 + 51)	515
Crop + Fish + Goat	1,78,047	493	420 (369 + %1)	576

3.7.13 Expected Output from Integrated Farming System Successful Models

1. Productivity gain - 2 to 3 times
2. Gain in net returns – 3 to 5 times
3. Resource saving – 40 to 50 %
4. Average regular net daily income – Rs 800 / household of 1 ha
5. Additional employment generation – 70 to 80 %
6. Reduction in greenhouse gases emission – 50%
7. House-hold nutritional security – 100%
8. Gender empowerment – 50%

3.7.14. Advantages of Integrated Farming System

1. Regular income and year round employment
2. Food and nutritional security
3. Eco recycle of agricultural residues / by product / wastes
4. Better Soil clarity for sustainable agriculture
5. Minimization of Pollution Hazards
6. Improvement of micro climate and soil micro flora
7. Conservation of natural resources
8. Possibility to minimize risk failures in productivity

3.7.15. Limitations of Integrated Farming System

1. Lack of awareness of sustainable integrated farming systems
2. Unavailability of varied integrated farming systems models
3. Lack of credit facilities at easy and reasonable interest rates.
4. Non availability of ensured marketing facilities for perishable commodities
5. Lack of deep freezing and storage facilities
6. Lack of timely availability of inputs for new enterprises in IFS models
7. Lack of marketing for products produced in low quantities for new enterprises included in IFS
8. Lack of knowledge education among farming community specially for rural youth in new enterprises of IFS

Fig 2 Integrated Farming systems

3.7.16. Further Thrust to Integrated Farming System

- There is need to create data base on Integrated Farming System in relation to type of IFS, infra-structure, economics sustainability etc., under different farming situations.
- Need to develop research modules of IFS under different holding sizes with economically and socially viable and acceptable systems.
- Assessment and refinement of technologies developed at research stations suitable to cultivators fields.

- Contingent planning to counter act weather and climatic threats under different farming situations.
- Development of cluster approach for new enterprises which produce products / by products in small amounts for marketing purposes
- Education of rural youth in ICT and other APPS for creating market linkage and remunerative farm incomes.

3.8 LET'S SUM UP

Sustainability development is the only way to promote rational utilization of resources and environmental protection without hampering economic growth. Integrated Farming Systems in this regard, holds special position of all farming systems as it meets all requirements of sustainable agriculture and in this system no by-product is wasted .By product of one enterprise becomes input for another linked enterprise. India has considerable livestock and crop wastes.

IFS are a promising approach for increasing overall productivity and profitability through recycling of farm waste and by products through efficient utilization of available sources. About 95% of input requirement of the system is self-sustained through resources recycling. As the number of enterprises increases profit margins also increases. Of farm enterprises linked/not linked to the enterprises can also be included. It could further generate employment opportunities of the farming community round the year and provide better economic and nutritional security. This can go long way to uplift rural life through increased farm income. Further it is evident that profit margin varied with eco systems under irrigated and rain fed conditions, management skills and socio economic conditions.

Farmers who have sufficient land and other resources can prefer integration of horticultural crops - fruits vegetable and floriculture as additional enterprise along with prevailing one. Where-as marginal farmers or landless farmers living in fruit orchard integrate apiary and mushroom into their existing farming systems. Farmers having sufficient irrigation water or living in low lying river bed areas can choose fishery as additional enterprise. Similarly, farmers within the vicinity of towns and cities can grow vegetable, green fodder and other requirements (flowers and green leaf garlands (Thoranam) and banana leaves and small plants for festivals, as per market demand and availability.

3.9 CHECK YOUR PROGRESS

1. What are requirements of sustainable agriculture which met by different type of farming?
2. Define Integrated farming system? Difference in Integrated Farming System and Farming System and what is difference to both?
3. What is concept of Integrated Farming System and reasons why Integrated Farming System is needed?

4. State the objectives of Integrated Farming System? And important elements of Integrated Farming System?
5. What are main factors that decide type of Integrated farming system?
6. What are major and allied components of Integrated Farming System?
7. Write in detail a successful model for North East Hill zone?
8. Which Integrated Farming System has maximum increase in net returns, per day return and employment generation and by how much percentage over cropping alone? Suggest Integrated Farming System enterprises for vicinity of towns and cities?
9. Write any three expected outputs from Integrated Farming System successful models?
10. Write five advantages and limitations of Integrated Farming System?
11. Suggest three further thrust points to Integrated Farming System?

3.10 FURTHER READING/ REFERENCES

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UNIT 4: INTEGRATED MANAGEMENT STRATEGIES
A. Integrated Nutrient Management

Highlights of the Unit

- Objectives
- Introduction
- Crop productivity trends in rain-fed regions
- Major constraints in improving the productivity and net returns of rain-fed agriculture
- Strategies for the development of rain-fed farming and Organic farming
- Development of rain-fed wastelands
- Policy changes and other support required for rain-fed agriculture
- Human resource development, training and consultancy
- Development of comprehensive database on rain-fed agriculture
- National and International perspective
- Let's sum up
- Check Your Progress
- Further readings/ references

4.A.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Major constraints in improving the productivity and net returns of rain-fed agricultural
- Land care and soil quality improvement
- Carbon sequestration through afforestation and efficient cropping systems
- Management of land and water on watershed basis
- Precision agricultural approach
- Strategies for the development of rain-fed farming
- Policy changes and other support required for rain-fed agriculture

4.A.1 INTRODUCTION

Rain-fed agriculture in India extends across 90.9 m ha that constitutes nearly 64% of the net cultivated area, contributing 40% of the food grains and supporting 40% of the Indian population of >1 billon, and plays a significant role in ensuring food security. There has been some decline in the rain-fed area because of development of irrigation facilities since

independence, but two-thirds of the net sown area still remains rain-fed. Even when the full irrigation potential of the country is realized, 50% of the net sown area is expected to continue to remain rain-fed. A host of food, fodder, and industrial crops are grown under rain-fed conditions.

Two-thirds of livestock population inhabits these areas. Among these, animals, small ruminants, like sheep and goat, predominate. These facts highlight the importance of dry farming in the country. To meet the growing demands for food grains, fodder, and fiber on a sustainable basis, it is inevitable to improve the production and productivity in these areas.

Rain-fed agriculture prevails in the desert terrain of Rajasthan in the northwest; the plateau region of Central India; the alluvial plains of the Ganga-Yamuna River Basin; the Central Highlands of Gujarat, Maharashtra, and Madhya Pradesh; the rain-shadow region of Deccan in Maharashtra; the Deccan Plateau in Andhra Pradesh; and the Tamil Nadu Highlands. About 15 million ha of rain-fed area represents the zone that receives <500 mm rainfall; another 15 million ha is in the 500–750 mm rainfall zone, and 42 million ha is in the 750–1,150 mm rainfall zone, with the remaining 25 million ha receiving >1,150 mm rainfall per annum.

4.A.2 CROP PRODUCTIVITY TRENDS IN RAINFED REGIONS

The productivity levels in the rain-fed areas have remained low across years. In general, the rain-fed ecosystem suffers from the problems of

a. Frequent droughts because of high variability in the quantity and distribution of rainfall
b. Poor soil health because of continued degradation and inadequate replenishment of nutrients
c. Low animal productivity because of an acute scarcity of green fodder
d. Low risk-bearing capacity of farmers, because of poor socio-economic base, low credit availability and infrastructure.

4.A.3 MAJOR CONSTRAINTS IN IMPROVING THE PRODUCTIVITY AND NET RETURNS OF RAINFED AGRICULTURE

The major constraints in improving the productivity and returns from rain-fed farming in India are as follows:

a. Erratic and uncertain rainfall, leading to moisture scarcity, droughts and failure of crops, especially annual crops.
b. Soil degradation and poor soil quality on account of dismally low amount of soil organic C (SOC) because of low returns of residues back to the soil, fast rate of decomposition because of high temperature and frequent inversion tillage, low fertility, excessive nutrient-removal-use gap because of low use of fertilizer inputs, water logging because of subsurface compaction and low infiltration, salinity, sodicity, acidity, compaction, hard setting, etc.

c. Fragmented and low holding size, leading to constraints in mechanization.
d. Poverty among growers and constraints in availability and purchase of essential inputs, such as seeds and fertilizers, bullock drawn small seed-cum-fertilizer drills, etc.
e. Lack of assured credit and financial support and marketing.
f. Inadequate infrastructure for postharvest value-addition and storage of produce; low procurement prices of agricultural commodities in general.
g. Inadequate earnings for livelihood from the farming profession because of low volume of business due to small holding size, low productivity, and low produce prices, etc. The consequences of these constraints are likely to lead the marginal and small-farming communities toward distraction from agriculture, migration to cities to look for alternate assured wages, suicides, etc. To mitigate these constraints and transform the rain-fed farming to an attractive option, there is a strong need for strategic planning and policy changes in a phased manner.

4.A.4 STRATEGIES FOR THE DEVELOPMENT OF RAINFED FARMING

The following multi-component strategies are suggested for improving the productivity and returns in rain-fed agriculture:

4.A.4.1 Land care and soil quality improvement: The predominant soil orders that represent rain-fed agriculture are: Alfisols, Inceptisols, Entisols, Vertisols, Oxisols, and Arid sols. Out of the total geographical area of 328.3 m ha, Entisols constitute 24.4% (80.1 m ha), Inceptisols 29.1% (95.8 m ha), Vertisols 8.02 % (26. 3 m ha), Aridisols 4.47% (14.6 m ha), Mollisols 2.43% (8 m ha), Ultisols 0. 24% (0.8 m ha), Alfisols 24.25% (79.7 m ha), Oxisols 0.08% (0.3 m ha), and non-classified soils 7.01% (23.1 m ha). About 187.7 m ha area, which constitutes 57.1% of the total geographical area, is degraded. Of the total degraded area, water erosion constitutes 148.9 m ha (45.3%), wind erosion 13.5 m ha (4.1%), chemical deterioration 13.8 m ha (4.2%), and physical deterioration 11.6 m ha (3.5%). Another 18.2 m ha land (5.5%), which is constrained by ice caps, salt flats, arid mountains and rock out crops, is not fit for agriculture at all. According to some other estimates, the total degraded area in India accounts for 120.7 m ha, of which 73.3 m ha is affected by water erosion, 12.4 m ha by wind erosion, 6.64 m ha by salinity and alkalinity and 5.7 m ha by soil acidity.

The soils in rain-fed areas have been severely affected because of

a. Loss of finer fraction of top soils, organic matter, and nutrients because of soil erosion and runoff processes
b. Virtually no or low recycling back of crop residues to the soil because of competing demand for crop residues as animal fodder
c. Temperature-mediated fast oxidation of organic matter because of frequent tillage operations, resulting in breaking up of micro-aggregates and exposure of SOC entrapped in them.

As lack of assured moisture does not support higher cropping intensity in these regions, contribution of root biomass to organic matter in the soil is also not very high. Apart from

these, low and imbalanced fertilizer use has also resulted in multi-nutrient deficiencies in rain-fed regions. Scarcity of moisture caused by an uncertain rainfall pattern does not give desirable return per unit of fertilizer use. Resultantly, soils encounter a diversity of constraints on account of soil quality and ultimately end up with poor functional capacity.

During the past, some research and developmental efforts have been made toward land care and soil-quality improvement for;

a. Location specific, soil-water conservation practices to conserve surface soil and its productive constituents
b. Adequate supplementation of nutrients and enhancement of organic carbon through integrated-nutrient management, green manuring, residue recycling, bio fertilizer application, tree-green leaf manuring, and by way of capitalization of legume effect
c. Method of soil-quality assessment
d. Land covers management and conservation tillage
e. Soil test-based fertilizer recommendation

Some of these past experiences have revealed that these efforts significantly contribute in checking land degradation and improving soil quality and its resilience. Despite these efforts, a considerable part of the research findings and technologies has not gone to the farmers. The farming community is still applying only a few kilograms of farmyard manure and inorganic fertilizers. Soil-water conservation practices have also not been adopted on an appreciable scale for several reasons. Research and extension focus needs to be continued on these aspects to generate adequate data through on-farm and on-station trials.

Considering the above, the following strategies are suggested for checking land degradation and improving soil quality.

a. Exploring the possibilities of surface-residue management, land cover, and residue recycling in a non-competitive manner-residue quality, decomposition pattern, carbon turnover, build-up of carbon pools, and carbon-turnover models.
b. Conjunctive use of organics and inorganics, off-season generation of biomass, green manuring, and tree-green leaf manuring.
c. Conservation tillage—standardization of methodology of growing crops under reduced or minimum tillage, method of seeding and appropriate seeding devices, weed control mechanism, frequency of tillage, quantification of fluxes of CO2 emission, water-relation studies, etc.
d. Efficient crops and cropping systems—identification and promotion of best carbon-sequestering systems, quantification of carbon contribution through roots, and fertilizer needs for higher root-biomass contribution.
e. Assessment of soil quality using standard methods—precise methods of computation of soil-quality index using key indicators and other parameters.
f. Quantification of soil fertility with inter/mixed-cropping systems.
g. Amelioration of problematic soils, such as saline and sodic soils and acid soil, using appropriate amendments and correcting waterlogged soils.

Apart from many other reasons, low fertilizer use in India is definitely one of the important causes of low yields. Efforts need to be made to redefine fertilizer doses by synchronizing with the anticipated water availability.

To ensure adequate and balanced fertilization, the following issues need to be given appropriate attention:

a. Mapping spatial variation in soil properties on a watershed scale and designing precise management practices for maximizing land productivity;
b. Identification and correction of deficient nutrients in rain-fed conditions;
c. Identification of nutritional constraints in soils and devising balanced fertilization schedules to correct them with special emphasis on cropping systems and promotion of customized fertilizer application;
d. Yield maximization by combining all limiting nutrients, and integrated nutrient-management practices;
e. Use of precision farming principles to enhance input-use efficiency;
f. Integration of database on soil fertility indicators through soil test network laboratories of the country, other organizations and agencies of central and state governments to develop fertilizer recommendation decision support system;
g. Development of soil health cards on a case-study basis as ready reckoners.
h. Identification of unexplored beneficial soil microorganisms and development of protocols for isolation, culturing, and mass multiplication; and
i. Identification of soil microorganisms for specific purposes, such as nutrient dissolution, mobilization and delivery, scavenging heavy metals and harmful compounds, degrading plastics, and suppression of pathogens.

4.A.4.2 Carbon Sequestration through afforestation and Efficient Cropping Systems:

Therefore, carbon sequestration through afforestation (energy plantation, perennials of industrial importance) and through efficient cropping systems under wider climatic and edaphic conditions is a potential subject that needs research thrust with special emphasis on rain-fed agriculture. The specific thrust areas in this regard are:

a. Management practices for enhancing the productivity of short-rotation forestry/energy plantations;
b. Quantifying belowground biomass accumulation for precise quantification of carbon;
c. Management practices that can enhance and maintain soil carbon levels in agroforestry systems/annual cropping systems;
d. Identification of potential tree-based systems for various degraded lands for enhancing biomass production and also income;
e. Carbon accounting in tree-based systems using tree-growth models; and
f. Exploiting carbon sink capacity of soil using efficient crops and cropping systems, their effective management, and appropriate conservation agricultural practices. Some of these practices were mentioned in the foregoing section.

4.A.4.3 Efficient Crops, Cropping Systems and Best Plant Types: Identification and recommendation of most efficient crops and cropping systems for rain-fed areas are a must for ensuring higher yields. A good number of improved varieties of millets, pulses, and oil seeds have been evaluated for their yield with reference to the local cultivars being grown by the farmers. A yield increase between 15% and 50% was reported when local cultivars were replaced by high yielding varieties. Further, the plants chosen for rain-fed regions must have good adaptability. The requirements of crops for better adaptation are

- **Drought escape:** Limited-season, small-stature crops that can respond to limited water supply. Further, short-season crops with fast-growing root system and high grain to straw ratio are also capable to escape drought.
- **Drought resistance:** Crops with extensive root system that obtain soil moisture during repeated water stress and crops capable of maintaining adequate cell water content when tissue moisture stress occurs.
- **Drought tolerance:** In the process of drought tolerance, crops prepare themselves to go in to temporary dormancy during water stress and resume normal situation on improvement of conditions.

4.A.4.4 Management of Land and Water on Watershed Basis: While managing the land and water on a watershed basis, the following points need to be considered:

- Emphasis on in situ moisture conservation to ensure adequate charge of soil profile and higher response to fertilizer and manure inputs.
- Soil water conservation, water harvesting, and its most efficient use through micro-irrigation techniques (drip and sprinkler irrigation) for high-value enterprises for maximum returns. The principle of "that harvested water is gold" need to be advocated.
- The central focus of soil water conservation should be individual farmer holdings instead of the macro approach being followed at present.
- Efficient use of existing ground water for higher output and most remunerative commodities only.
- Development of additional water resources wherever possible through linkage of canals, rivers, lifts irrigation, etc.
- Incentives and 'community movement' for rooftop water harvesting, percolation, and efficient use.
- Development of effective policies for water management and its sharing at community level using Israeli/Californian models.

4.A.4.5 Adoption of Farming Systems Approach by Diversifying Enterprises: Farming systems approach by diversifying enterprises is most needed in rain-fed agriculture. This will help in increasing the productivity and profitability and reducing poverty and the extent and magnitude of risks in rain-fed farming. Different modules could be alternative agricultural practices, such as Agri-horticulture, Silvi-pasture, Agroforestry systems, Livestock integration, rain-fed horticulture, medicinal and aromatic plants, etc. There is a need to initiate special incentives and programs for providing seeds of forage crops,

grasses, seedlings of horticultural plants and top feed-tree species through suitable nurseries. Development of infrastructure for micro-irrigation and post-harvest processing is essential. Assured marketing linkage needs to be established.

4.A.4.6 Mechanization for Timely Agricultural Operations and Precision Agricultural Approach: Rain-fed agriculture operations are most time-bound and hence suitable mechanization for timely and precision agricultural operations is essential. Postponement of sowing date of rain-fed crops can lead to a risk of losing 15% to 100% yield of crops. Special drive is needed to ensure the availability of bullock- and tractor-drawn small and medium implements. The state-based agro-industries and promotion of custom-hiring services for implements, etc., in rural areas need to be strengthened by employing educated rural youth. Provision need to be made for subsidized purchase of implements by the farmers. These efforts should help replace the age-old practice of broadcast (spreading) of seed and fertilizer randomly in field. A significant difference in fertilizer- and moisture-use efficiency and yield enhancement can be expected out of these initiatives, if implemented at a mass scale.

4.A.4.7 Post-Harvest, Cold Storage, Value-Addition Modules: To enhance the value of the produce and enable farmers to obtain higher price, it is essential to strengthen the post-harvest processing units and cold storage facilities. These will not only help the farmers in enhancing their income, but also in providing/generating employment for the rain- fed area rural community.

4.A.4.8 Assured Employment or Wage System: Recommendation for providing assured employment to at least one member of a farm family and landless labourers and off-season employment to other members of the family could very much support/sustain their livelihood. The salary of the lowest paid government employee in India at present is nearly rupees one lakh/year, which is approximately equal to US$2000/year.

The small and marginal farmers, who possess 1–2 hectares of rain-fed land holdings, despite using their entire family as labor input in the agricultural enterprise for a whole year (if two crop seasons are available), might not even get 1/5 of the above income as net return under prevailing price policy for agricultural commodities. Even after discounting for the marginal subsidies that a farmer is availing on some of the inputs, the amount he gets as net return is miserably low from the present kind of crops/cropping systems/commodities. Hence, employment support is inevitable to make him stay in this profession.

It is worthwhile to mention here that the Government of India has already initiated good efforts in this direction by enacting a program viz. National Rural Employment Guarantee Act (NREGA), through which rural families are getting assured jobs (wages) for at least 100 man-days. Many more improvements are expected in this program in future.

4.A.5 ORGANIC FARMING

There is a scope to introduce organic farming in some selected rain-fed crops, which may be helpful in increasing the income of the farmers as well as improving soil quality.

4.A.6 DEVELOPMENT OF RAINFED WASTELANDS

- To harness the potentials and to make efficient use of the rain-fed wastelands, it is essential to rehabilitate them by using selective technological modules. These are:
- Soil and rainwater conservation through terracing, bunding, trenching, water-storage ponds, vegetative barriers, rainwater harvesting, increase in water storage, and recycling;
- Encouraging natural vegetation, planting and sowing of multipurpose trees, shrubs, grasses, legumes, pastures, fruit, timber, and fodder species;
- Growing of biodiesel plants such as Jatropha, Pongamia, etc., considering market availability;
- Controlling wind erosion through shelter belt/wind-break plantations; • Stabilization of sand dunes;
- Integrated soil fertility management;
- Ravine reclamation through mechanical and vegetative means; • Rehabilitation of mine spoils;
- Management/utilization of saline lands and industrial effluents; and
- Linking employment for landless laborers with wasteland management. In these activities, community participation is a must.

4.A.7 POLICY CHANGES AND OTHER SUPPORT REQUIRED FOR RAIN-FED AGRICULTURE

Besides technological interventions, appropriate changes in policies and provision of other support system are needed for the development of rain-fed agriculture and ensuring an adequate income and livelihood of the farming community. Some of the important policy issues are listed below:

- Provision for special subsidies on certain inputs;
- Revision of procurement prices of rain-fed agricultural commodities periodically;
- Provision for soft loans to small and marginal rain-fed farmers/growers;
- Family health cards and medical and crop insurance to the rain-fed farmers;
- Soil health cards and periodical updates;
- Kisan credit cards for purchasing seed, fertilizer, and other inputs instantaneously whenever needed without delay;
- Quick drought monitoring and relief'
- Reservation and priority in providing assured jobs;
- Assured marketing;

- Development of contract farming and cooperative farming modules for improving the performance of rain-fed agriculture. A mechanism of "land for mutual working but with individual titles" needs to be created;
- Capacity building and training of farmers in specialized farm activities; knowledge buildup initiatives need to be started for the farming community; and
- Opening of 'information hubs' and Agri-clinics for better decisions and technical support.

4.A.8 HUMAN RESOURCE DEVELOPMENT, TRAINING AND CONSULTANCY

The persons associated with the technical functionaries on rain-fed agriculture need periodical exposure to the latest advances in rain-fed agricultural technologies being developed abroad. If required, it is desirable to establish a network of consultants from suitable countries for executing the mega developmental projects on rain-fed agriculture in India. Special exposure trainings of short duration are required for the grassroots level and cutting-edge personnel involved in implementation of watershed and rain-fed agricultural development programs in various states.

Some of the training aspects are listed below:

- Package of practices of rain-fed crops.
- Alternate land-use system.
- Control measures of different pests and diseases, and integrated pest management.
- Concept of integrated watershed management.
- Strategy and approach of watershed management.
- Criteria of site selection.
- Priorities of watershed planning and peoples participation.
- Survey and watershed planning.
- Preparation of base map for watershed and estimates for financial outlay.
- Contingency crop planning.
- Improved farm implements.
- Pasture development.
- Dryland horticulture.
- Agro-climatologic parameters.
- Land capability classification.
- Land leveling.
- Chain survey.
- Gully control measures.
- Water-harvesting structures.
- PRA technique.

4.A.9 DEVELOPMENT OF COMPREHENSIVE DATABASE ON RAINFED AGRICULTURE

There is a need to develop a comprehensive database on rain-fed agriculture for periodic planning. The database could be from the viewpoint of national and international perspective.

4.A.9.1 NATIONAL AND INTERNATIONAL PERSPECTIVE

National perspective

- Climate, land, and water resources.
- Crops and cropping systems and input-use pattern and their productivity.
- Forest and environment, coverage, status, threats, if any.
- Complete profile of human resources and their socio-economic conditions.
- Credit marketing and R & D organization.
- Agricultural and rural development programs launched on rain-fed agriculture in the country by different ministries—their success, functioning, budget, scope for convergence, etc.
- Database on allied activities, such as health and education guarantees, insurances, Kisan credit cards, old-age pensions, subsidies on agricultural inputs, such as seed, fertilizers, insecticides/pesticides, etc., drip irrigation, lift irrigation, fertigation, seed production, mechanization level, small implements, tractors, electricity/energy, post-harvest processing, export, etc.

International perspective

- Database on land and water resource for different countries.
- Technological hubs on rain-fed farming.
- Data- and information-sharing mechanism.
- Frequent exchange of experts in rain-fed farming, consultancies for mega projects, etc.
- Development of international commissions for rain-fed farming for coordinating research and technology transfer among different countries.

4.A.10 SOME LESSONS LEARNED

Some of the lessons learned on various aspects of rain-fed farming are briefly enumerated below:

- There has been an increase in rain-fed area under oilseeds and cotton (*Gossypium* spp.) to the extent of 130% and 50% increase, respectively. Area under coarse cereals decreased by 25% and no significant change was recorded for pulses. Further, an increase of 50%–100% in cotton and maize (*Zea mays*) was observed because of additional irrigation for these crops.
- Timely sowing of rain-fed crops makes a significant difference in yields. A delay of 9–14 days in sorghum and upland rice (*Oryza sativa*) resulted in yield losses of 43–137

and 36 kg/ha/day, respectively. Similarly, sowing castor (*Ricinuscommunis* L.) during the second half of July reduced bean yield up to 850–250 kg/ha. A 15 day delay in sowing of sorghum caused a reduction in grain yield of 850 kg/ha.

- Tillage plays an important role in influencing the conservation of soil and rainwater. Deep tillage (25–30 cm) helps in soil pulverization, increased rainwater infiltration, and better root growth, thereby increasing crop yield. Off-season or pre-monsoon tillage has a significant impact on weed control and rainwater infiltration. Grain yields of sorghum and barley (*Hordeumvulgare*) were 2,600 and 1,570 kg/ha with off-season tillage compared with 1,870 and 1,370 kg/ha without off-season tillage.
- Studies on reduced-till farming indicated that conventional tillage using recommended fertilizer and weeding, with or without off-season tillage, resulted in higher grain yields of barley, rice, lentil, wheat, soybean, groundnut, finger millet, and pearl millet.
- Incorporating sorghum stubbles at 5 t/ha to cover 69% soil surface resulted in a 0.24 t/ha soil loss and 25 mm runoff compared with a 1.58 t/ha soil loss and 83 mm runoff when this treatment was not applied.
- Mulching also reduced soil temperature and resulted in 25% greater moisture storage in the 0–30 cm soil profile.
- Cultivation during the vegetative stage enhanced the productivity of castor, sunflower, and pigeon pea by 15–20% compared with no cultivation.
- In Vertisols, spreading of crop residues at 5 t/ha enhanced the productivity of post-rainy season sorghum and sunflower by about 25% probably through efficient utilization of stored soil moisture.
- In Alfisols, incorporation of corn residue at 4 t/ha increased crop yield in a succeeding crop by about 80%.
- Sorghum yield under vertical mulching at 5-m intervals was about 25% higher than that without mulching.
- Silvipasture systems involving palatable grasses like Anjan grass (*Cenchrusciliaris*L .) and legumes Stylo (*Stylosantheshamata* (L.) Taubert) with trees such as Subabul (*Leucaenaleucocephala* Lam.), Siris (*Albezzialebbeck* (L.) Benth), Anjan (*Hardwickiabinata*Roxb.), and Sisso (*Dalbergiasisso*Roxb.) were found to be more productive and profitable in the drylands.

4.A.11 LET'S SUM UP

Rain-fed agriculture in India needs to be re-examined as far as technological and policy interventions are concerned. The suggestions made in the foregoing sections, if implemented systematically, would definitely help in increasing the productivity and net income of the rain-fed area farmers in the country. Ultimately, the objective is to make rain-fed farming a viable livelihood option on a sustainable basis while also protecting the environment, and to help the farming community to stay in agriculture and distract farmers from migration to cities for alternative jobs.

4.A.12 CHECK YOUR PROGRESS

1. What are the major constraints in improving the productivity and net returns of rainfed agricultural?
2. What ate the measures to improve soil quality?
3. What is carbon sequestration?
4. States efficient cropping systems?
5. What are different measures of management of land and water on watershed basis?
6. Describe precision agricultural approach?
7. Describe the various strategies for the development of rainfed farming?
8. Explain the policy changes and other support required for rainfed agricultural?

4.A.13 FURTHER READINGS/ REFERENCES

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UNIT 4: INTEGRATED MANAGEMENT STRATEGIES
B. Integrated Pest Management

Highlights of the Unit

- Objectives
- Introduction
- Losses due to pests
- Evolutionary trends in chemical-based pest management
- Intensive agriculture and pesticide use in India
- Sustainable agriculture and integrated pest management
- Tools of integrated pest management
- Major obstacles, strategies and essentials for implementation integrated pest management
- Let's sum up
- Check Your Progress
- Further readings/ references

4.B.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Losses due to pests
- Evolutionary trends in chemical-based pest management
- Intensive agriculture and pesticide use in India
- Sustainable agriculture and integrated pest management
- Tools of integrated pest management
- Major obstacles for implementation integrated pest management
- Strategies for implementation of integrated pest management
- Essentials for implementation of integrated pest management

4. B.1 INTRODUCTION

Over the next three decades, production of food grains in India has to increase at least 2 million tons a year to meet the food demand of the growing population. In the past, agricultural production increased through area expansion and increasing use of high yielding seeds, chemical fertilizers, pesticides and irrigation water. Now, prospects of raising agricultural production through area expansion and application of existing technologies appear to be severely constrained.

Land frontiers are closing down, and there is little, if any, scope to bring additional land under cultivation. Green revolution technologies have now been widely adopted, and the process of diminishing returns to additional input usage has set in. Concurrently,

agricultural production continues to be constrained by a number of biotic and abiotic factors. For instance, insect pests, diseases and weeds cause considerable damage to potential agricultural production.

Evidences indicate that pests cause 25 percent loss in rice, 5-10 percent in wheat, 30 percent in pulses, 35 percent in oilseeds, 20 percent in sugarcane and 50 percent in cotton. The losses though cannot be eliminated altogether, these can be reduced. Until recently, chemical pesticides were increasingly relied upon to limit the production losses. Pesticide use in India increased from a mere 15 g/ha of gross cropped in 1955-56 to 90 g/ha in 1965-66. Introduction of green revolution technologies in mid-1960s gave a fillip to pesticide use, and in 1975-76, it had increased to 266 g/ha, and reached a peak of 404 g/ha in 1990-91. Although, there is a paucity of reliable time-series information on pest-induced production losses, anecdotal evidences suggest increase in losses, despite increase in the pesticide use.

The paradox is explained in terms of rising pest problem, technological failure of chemical pesticides and changes in production systems. Nevertheless, pesticide use has started declining since 1990-91, reaching 265g/ha in 1998-99, without much affecting the agricultural productivity. The declining trend in pesticide use in agriculture during the 1990s can be attributed to central government's fiscal policy and technological developments in pest management.

During 1990s, taxes were raised on pesticides and phasing out of subsidies was initiated. Programmes on training of both the extension workers and farmers in the Integrated Pest Management (IPM) were started throughout the country. In fact, the Government of India had adopted IPM as a cardinal principle of plant protection in 1985.

Notwithstanding these initiatives, adoption of IPM has not been encouraging as bio-pesticides capture hardly 2 percent of the agrochemical market. This overview provides a synthesis of the papers presented at different fora and identifies technological, socio-economic, institutional and policy issues important in making IPM work under field conditions.

4.B.1.1 Losses Due to Pests: Insect pests, diseases and weeds are the major constraints limiting agricultural productivity growth. It is estimated that herbivorous insects eat about 26 percent of the potential food production. Emerging problems of insecticide resistance, secondary pest outbreak and resurgence further add to the cost of plant protection. Annual crop losses due to insect pests and diseases in India are estimated to be 18 percent of the agricultural output. Losses caused by specific pests may be higher. *Helicoverpa* spp. in cotton causes losses up to 50 percent. Various study revealed that *H. armigera* (American bollworm) alone causes an annual loss of about Rs.1000 crores. The production losses have shown an increasing trend over the years. In 1983, the losses due to insect pests were estimated worth Rs.6, 000 crores, which increased to Rs.20, 000 crores

in 1993 and to Rs.29, 000 crores in 1996. New pests have appeared due to the changes in the cropping patterns and the intensive agricultural practices.

4.B.1.2 Evolutionary Trends in Chemical-Based Pest Management: Until the beginning of 20th century, farmers relied exclusively on cultural practices such as crop rotation, healthy crop variety, manipulations in sowing dates, etc. to manage the pests. Use of pesticides, although began in 1870s with the development of arsenical and copper-based insecticides, discovery of pesticidal properties of DDT during the World War II revolutionized the pest control. DDT was effective against almost all-insect species and was relatively harmless to the humans, animals, and plants. It was effective at low application rates, and was also less expensive, hence the Indian industries too joined the race. Farmers were amazed with its effectiveness and started to use it increasingly particularly during the green revolution era.

As a result of rising demand, the pesticide industry rapidly expanded its research on synthetic organic insecticides as well as on other chemicals controlling the pests. The negative externalities of chemical pesticides, however, started emerging soon after the introduction of DDT. Producers then turned to the more recently developed, and much more toxic, organophosphates (OP) and pyretheroid insecticides, which resulted in development of resistant strains. Most of the pesticides were originally based on the toxic heavy metals such as arsenic, mercury, lead and copper.

Pesticides often kill the natural enemies along with the pests. With natural enemies eliminated, it is difficult to prevent recovered pest populations from exploding to higher and more damaging levels, and often developing resistance to chemical pesticides. Repeated applications of chemical pesticide only repeat this cycle. At low yields, benefits from pest control were not huge. However, as yields started increasing, pesticide use started becoming widespread. Their adverse effects on the environment and human health also soon became apparent. During the early 1960s, the public concerns about these effects were galvanized by Rachel Carson in her classic 'Silent Spring', published in 1962. Indiscriminate, excessive and continuous use of pesticides acted as a powerful selection pressure for altering the genetic make-up of the pests. Naturally resistant individuals in a pest population were able to survive onslaughts of the pesticides, and the survivors could pass on the resistance traits to their generations. This resulted in a much higher percentage pest population being resistant to pesticides. At present, the number of weed species resistant to herbicides are estimated to be 270, and plant pathogens resistant to fungicides are 150. Resistance to insecticides is common and more than 500 insect species have acquired resistance to the pesticides.

4.B.1.3 Intensive Agriculture and Pesticide Use in India: In India, pesticide use has been increasing at an annual rate of 2.5 percent since early 1970s. About 96,000 tons of technical grade pesticides are currently produced in the country, of which two-thirds are used in agriculture. The adoption of the high yielding cereal varieties led to manifold increase in the crop yields. Maintaining higher yields also led to a dramatic increase in the pesticide

use; from 5,700 tons in 1960 to 46,195 tons in 2000. Although per hectare pesticide use in India is about 250g, pesticides are used indiscriminately. About half of the total pesticides used in agriculture goes towards controlling insect pests and diseases of cotton, which occupies only 5 percent of the total cultivated area. Cotton receives as many as 15-20 rounds of insecticide sprays right from the vegetative stage till its maturity. According to the estimates by many scientists, one hectare of cotton receives 3.75kg of pesticides. Rice is with an area share of 24 percent accounts for 17 percent of the total pesticide use.

Indian 'Green Revolution', one of the greatest success stories in the world, with dramatic impact on the food security, was based on principles of intensive agriculture. However, the intensive agriculture has led to the newer problems such as excessive and untimely use of irrigation water, erosion of genetic resources caused by the replacement of rich diversity of the traditional crop varieties with a few high yielding varieties, and inappropriate use of critical inputs such as chemical fertilizers and pesticides. Thus, with intensification of agriculture and consequent increase in genetic uniformity of crops, the incidence of insect-pests, diseases, nematodes and weeds has also increased. The pests that hitherto were of novelty have become the key pests affecting a number of crops.

One notable feature of intensive agriculture was increased use of pesticides, particularly during the green revolution years. Until 1995-96, the major group of chemical pesticides used in agriculture was that of insecticides (80%), followed by fungicides (10%) and herbicides (7%). Thereafter, the share of insecticides declined with simultaneous increase in the shares of herbicides and fungicides. The share of insecticides in 1999-2000 was 60 percent, of fungicides, 21 percent, and of herbicides, 14 percent. Although the consumption of pesticides per hectare has remarkably come down, the use of pesticides on different crops varies remarkably. Per hectare consumption of pesticides started declining since early 1990s. This is obviously due to increasing awareness of ecological concerns and IPM initiatives taken up by different state governments. There are substantial regional variations in pesticides consumption and its trend. Earlier, Andhra Pradesh, Karnataka and Gujarat used to account for bulk of the total pesticide consumption, but this has come down substantially due to initiatives taken up state governments. Current statistics show Uttar Pradesh, Punjab and Haryana as the major consumers.

4.B.1.4 Sustainable Agriculture and Integrated Pest Management: The solution to the pesticide externalities lies in the implementation of IPM, which combines the use of different pest control strategies (cultural, resistant varieties, biological and chemical control). IPM is thus more complex for the producer to implement, as it requires skills in pest monitoring and understanding of the pest dynamics, besides the cooperation among the producers en-mass for effective implementation. During 1960s when the IPM began to be promoted as a pest control strategy, there were fewer IPM technologies available for field application. During 1970s, research generated some novel products and knowledge for successful implementation of IPM in crops like rice, cotton, sugarcane and vegetables. However, the exaggerated expectations about the possibility that dramatic reduction in pesticide use could be achieved without significant decline in crop yields as

a result of adoption of IPM could not be realized. IPM is an ecologically based strategy that focuses on long-term solution of the pests through a combination of techniques such as biological control, habitat manipulation, modification of agronomic practices, and use of resistant varieties.

Embracing a single tactic to control a specific organism does not constitute IPM, even if the tactic is an essential element of the IPM system. Integration of multiple pest suppression techniques has the highest probability of sustaining long term crop protection. Pesticides may be used to remove/prevent the target organism, but only when assessment with the help of monitoring and scouting indicates that they are needed to prevent economic damage.

Pest control tactics, including pesticides, are carefully selected and applied to minimize risks to the human health, beneficial and non-target organisms, and environment. In the context of crop protection, sustainability refers to the substitution of chemicals and capital with farm grown biological inputs and knowledge, aimed at reduction in the cost of production without lowering the yields. Sustainability builds on the current agricultural achievements, adopting a sophisticated approach that can maintain high yields and farm profits without degrading the resources. Sustainable agriculture is a reality based on the human goals and on the understanding of the long-term impact of human activities on the environment and on other species. This philosophy combines the application of prior experience and the latest scientific advancements to create integrated, resource-conserving, equitable farming systems.

The systems approach minimizes environmental degradation, sustains agricultural productivity, promotes economic viability in both the short and long run, and maintains quality of the life. Sustainable farming practices commonly include:

Crop rotations that mitigate weeds, disease, insect and other pest problems; provide alternative sources of soil nitrogen; reduce soil erosion; and reduce risk of water contamination by agricultural chemicals

- Pest control strategies include integrated pest management techniques that reduce the need for pesticides by practices such as scouting/ monitoring, use of resistant cultivars, timing of planting, and biological pest controls
- Increased mechanical/biological weed control; more soil and water conservation practices; and strategic use of green manures
- Use of natural or synthetic inputs in a way that poses no significant hazard to humans or the environment.

4.B.2 TOOLS OF INTEGRATED PEST MANAGEMENT

Monitoring: Crop monitoring, that keeps track of the pests and their potential damage, is the foundation of IPM. This provides knowledge about the current pests and crop situation and is helpful in selecting the best possible combinations of the pest management methods. Pheromone traps have got advantage over other monitoring tools

such as light and sticky traps. Being selective to specific pest, they have proven their usefulness in large scale IPM validations in cotton, basmati rice, chickpea and pigeon pea.

Pest resistant varieties: Breeding for pest resistance is a continuous process. At the same time the pests also, particularly the plant pathogens, co-evolve with their hosts. Thus, gene transfer technology is useful in developing cultivars resistant to insects, plant pathogens and herbicides. An example of this is the incorporation of genetic material from *Bacillus thuringiensis* (*Bt*), a naturally occurring bacterium, in cotton, corn, and potatoes, which makes the plant tissues toxic to the insect pests. Scientific community is impressed by its huge potential in managing the pests, but is also concerned about the possibility of increased selection pressure for resistance against it and its effects on non-target natural fauna. However, due to ethical, scientific and social considerations, this potential technology has been surrounded by controversies.

Cultural pest control: It includes crop production practices that make crop environment less susceptible to pests. Crop rotation, fallowing, manipulation of planting and harvesting dates, manipulation of plant and row spacing, and destruction of old crop debris are a few examples of cultural methods that are used to manage the pests. Planting of cover crops, nectar producing plants and inter-planting of different crops to provide habitat diversity to beneficial insects are important management techniques. Cover crops, often legume or grass species, prevent soil erosion and suppress weeds. A cover crop can also be used as a green manure, which is incorporated in the soil to provide nitrogen and organic matter to the subsequent crop. When incorporated in the soil, some cover crops of the *Brassica* family have the ability to suppress nematode pests and wilt diseases. Left in the field as residues, rye and wheat provide more than 90 percent weed suppression. Cultural controls are selected based on knowledge of pest biology and development.

Physical or mechanical controls: These are based on the knowledge of pest behavior. Placing plastic-lined trenches in potato fields to trap migrating Colorado potato beetles is one example of the physical control. Shaking of the pigeon pea plant to remove *Helicoverpa* larvae is a common practice in pigeon pea growing areas. Hand picking of insect pests is perhaps the simplest pest control method. Installation of dead as well as live bird perches in cotton and chickpea fields has proved effective in checking the bollworm infestation. Using mulches to smother weeds and providing row covers to protect plants from insects are other examples.

Biological controls: These include augmentation and conservation of natural enemies of pests such as insect predators, parasitoids, parasitic nematodes, fungi and bacteria. In IPM programmes, native natural enemy populations are conserved, and non-native agents may be released with utmost caution. Trichogramma spp. are the most popular parasitoids being applied on a number of host crops. A number of microorganisms such as Trichoderma spp., *Verticillium* spp., *Aspergillus* spp., *Bacillus* spp. and *Pseudomonas* spp. that attack and suppress the plant pathogens have been exploited as biological control agents.

Chemical controls: Pesticides are used to keep the pest populations below economically damaging levels when the pests cannot be controlled by other means. Pesticides include both the synthetic pesticides and plant-derived pesticides. Synthetic pesticides include a wide range of man-made chemicals. These are easy to use, fast-acting and relatively inexpensive. Ideally, pesticides should be used as a last resort in IPM programmes because of their potential negative effect on the environment.

Pesticides with the least negative impacts on non-target organisms and the environment are most useful. Fortunately, new generation pesticides with novel modes of action and low environmental effects are being developed and registered for use. Pesticides that are short-lived or act on one or a few specific organisms fall in this class. Economic threshold assessment is based on the concept that most plants can tolerate at least some pest damage.

Much research has been done to determine the damage thresholds for a variety of crops and pest situations, yet the studies are inconclusive. In an IPM programme where the economic threshold is known, chemical controls are applied only when the pest's damaging capacity is nearing to the threshold, despite application of other alternative management practices.

Botanical pesticides can be prepared in various ways. They can be as simple as raw crushed plant leaves, extracts of plant parts, and chemicals purified from the plants. Pyrethrum, neem, tobacco, garlic, and pongamia formulations are some examples of botanicals. Some botanicals are broad spectrum pesticides. Botanicals are generally less harmful to the environment, because of their quick degrading property. They are less hazardous to transport. The major advantage is that these can be formulated on-farm by the farmers themselves.

4.B.3 MAJOR OBSTACLES FOR IMPLEMENTATION OF INTEGRATED PEST MANAGEMENT

Although, IPM has been accepted as the most attractive option for protection of crops from the ravages of pests, implementation at the farmer's level has been limited. Pesticides continue to dominate and their injudicious use represents the greatest threat to IPM. For an effective implementation strategy, it is necessary to identify the obstacles to its dissemination, some of which are:

- Low awareness and innovativeness of extension personnel and target groups
- Inadequate interaction between research and extension agencies
- Problem of timely and adequate supply of quality inputs, including bio control agents and bio pesticides
- Complexity of IPM vs simplicity of chemical pesticides
- The dominant influence of pesticide industry
- Non-availability of location-specific IPM modules for many crops.

4.B.4 STRATEGIES FOR IMPLEMENTATION OF INTEGRATED PEST MANAGEMENT

The IPM packages tested at several research centers vis-a-vis the farmers' practices indicate superiority of the former. IPM practices enabled reduction in the number of chemical sprays. IPM system also resulted in increase of natural enemies by three-fold, reduced the insecticide and environmental pollution. An integrated strategy for the management of major pests and diseases is possible by

a. Breeding new varieties with built-in resistance,
b. Evolving efficient methods of pest control through pest surveys and monitoring, and
c. Biological control of pests with the help of conservation and augmentation of natural enemies like parasites, predators and insect pathogens.

Economically viable integrated pest management strategies have been developed for the control of major pests in rice, cotton, pulses, sugarcane, etc. Control of *Pyrilla* and top borer of sugarcane, mealy bug of coffee, lepidopterous pests affecting cotton, tobacco, coconut, sugarcane, etc. are a few examples where success has been achieved through the release of biocontrol agents. A major achievement has been the development of mass rearing technology for biocontrol agents such as *Trichogramma* spp., *Chrysoperla* spp. and nuclear polyhedrosis viruses (NPV) of Heliothis and Spodoptera. Indian scientists and extension workers are aware of negative externalities of the pesticides, and the concept of economic thresholds.

The Department of Biotechnology, Government of India, provides financial assistance to the State Agricultural Universities and other research organizations for developing and producing bio-pesticides and bio-control agents. A number of bio-pesticide production units and plant protection clinical centers have been established and strengthened in recent years. As a result, the use of bio-pesticides and bio-control agents in India is rising, but it has not reached the desired level. The bio-pesticides are cheaper than the chemical pesticides. Besides being eco-friendly, they do not pose risk of resistance development. A rough estimate of demands for different bio-pesticides proposed in the IXth Five Year Plan is given in Table 3. The estimates look to be difficult to meet unless a mission-oriented approach is followed. It appears that the concept of using bio-pesticides and bio-control agents among the farmers is still in infancy. Only 1 percent of 143 million hectares cropped area confined to only about 2500 villages of the 6 lakh villages in the country has been covered under IPM. Thus, there is a need to synthesize, validate and promote appropriate location-specific IPM modules.

4.B.4.1 Essentials for Implementation of Integrated Pest Management

- Availability of location-specific IPM modules, which are ecologically sound, economically viable and socially acceptable
- High level of target group participation
- Area-wide dissemination strategy · Removal of obstacles in dissemination of IPM
- Measuring, evaluating and publicizing the impacts of IPM.

Conservation of natural enemies of pests and their augmentation is of prime importance. Besides, the intrinsic property of renewability, reversibility and resilience of botanicals and bio pesticides make them most dependable tools for sustainable IPM. Hence, to maintain ecological balance and to manage the pests, the use of bio-agents and bio pesticides/botanicals must receive priority attention.

4.B.5 LET'S SUM UP

There is an emerging consensus that modern petrochemical-based farming is unsustainable and there is a need to develop and promote ecological approaches to food production. Biotechnology offers a great scope to do this. The most obvious and apparently environment-friendly alternative to pesticides is to follow the naturally occurring biological approaches. Many plant species have been reported to possess pesticide and pest growth inhibiting properties, but their potential remains untapped by the industry. Holistic planning provides farmers with the management tools they need to manage biological complex farming systems in a profitable manner. A successful IPM programme requires time, money, patience, short- and long term planning, flexibility and commitment. The research managers must spend time on self-education and making contacts with extension and research personnel to discuss farming operations, which vary widely. This would aid in developing integrated plans. The government could create policy environment for promotion of IPM. The central and state governments must take lead in changing the pest control picture through measures that would make chemical control less attractive through legislation, regulatory and fiscal measures. Government of India, is committed to the development and promotion of IPM in the country. It is the top priority of the Government of India to provide safe and effective technologies to protect against unacceptable losses due to insect pests, weeds and diseases.

4.B.6 CHECK YOUR PROGRESS

1. Describe in details the crop production losses due to pests?
2. Write about evolutionary trends in chemical-based pest management?
3. Write about pesticide use in India
4. Describe sustainable agriculture and integrated pest management?
5. Write about various tools of integrated pest management?
6. What are the major obstacles for implementation integrated pest management?
7. Describe the strategies for implementation of integrated pest management?
8. What are the essentials for implementation of integrated pest management?

4.B.7 FURTHER READINGS/ REFERENCES

- Principles and Concepts of Integrated Pest Management, available at https://niphm.gov.in/Recruitments/ASO-Pathology.pdf
- Integrated Pest Management (IPM) Principles, available at https://www.nrdnet.org/sites/default/files/integrated_pest_management.pdf
- FAO, Integrated pest management of major pests and diseases in Eastern Europe and the Caucasus available at http://www.fao.org/3/a-i5475e.pdf
- S. S. Rana, Integrated Pest Management, available at http://www.hillagric.ac.in/edu/coa/agronomy/lect/agron-3610/Lecture-17-and-18-IPM.pdf

UNIT 5: CLIMATE CHANGE: IMPACT, ADAPTATION AND MITIGATION IN AGRICULTURAL SECTORS

Highlights of the Unit

- Objectives
- Introduction
- Climate change – Overview, contributing factors
- Impacts of climate change – Indian Experience
- Recent observations on climate change and its impact on allied sectors
- Mitigation and adaptation towards climate smart agriculture
- Let's sum up
- Check Your Progress
- Further reading

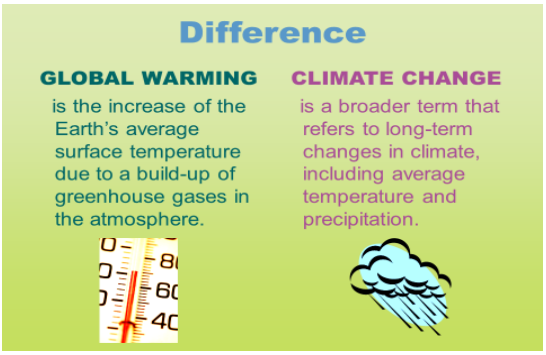
5. 0 OBJECTIVES

After completing this unit, the learners will be able to understand:

- The Concept of climate change, factors influencing the climate change and impact on Climate change,
- The various Adaptation and Mitigation options available to address the Climate change

5.1 INTRODUCTION

According to IPCC, Climate change as defined by Intergovernmental Panel on Climate Change (IPCC) "refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer".



Box -1: Important concepts

VULNERABILITY TO CLIMATE CHANGE: It is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, it's Sensitivity, and it's Adaptive Capacity.

Vulnerability = function [exposure (+); sensitivity (+); adaptive capacity (-)]

Vulnerability = potential impact (sensitivity x exposure) – adaptive capacity

Exposure : the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.

Sensitivity: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Potential Impact: The impacts of climate change are the effects of climate change on natural (e.g. water resources, biodiversity, soil, etc) and human systems (e.g. agriculture, health, tourism, etc). Potential impacts are all impacts that may occur given a projected change in climate, without considering adaptation.

Adaptive Capacity: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantages of opportunities, or to cope with the consequences.

Source: adopted from IPCC

Click the link to more on climate change https://bit.ly/2XpyHBI

Climate change is now accepted as real, pressing and global problem by both scientific and public alike. Recognizing the change in climate has led multilateral negotiations across the globe to minimize or negate the impacts of climate change on the biosphere. Studies show that climate change has conspicuous impacts on hydrology, cryosphere, meteorology, lithology, topography, etc. as a result, the entire, sectors viz., primary (mining, fishing, agriculture etc.), secondary (oil refinery, manufacturing, food processing etc.) and tertiary (financial, education, banking, etc.) have incurred a loss. Of the three sectors, primary that too, agriculture is considered a climate-sensitive sector. Several perceptions and opinion studies held by a range of scientific and academician cite that the communities across the globe perceive that the climate has changed. Thus, the chapter on climate change elucidates the impacts of climate change on agriculture and explicitly discusses the mitigation and adaptation/extension advisory services within the framework of climate smart agriculture or climate smart villages.

5.2.1 Climate change – Overview: Climate change alters the production systems, thereby threatens the food security of the billions of population across the globe. Weather is the single largest source of variability that affects farm output drastically. About 20-80 % of the inter-annual variability occurs due to variability in weather parameters. The changes in weather bring either direct physiological stress in the crops or indirect pest and diseases or both (PIB, 2019). Further, the climate change would be a threat to the livelihood of 36 % or 2.6 million of the global population, because the income source of these is directly dependent on agriculture and allied activities (Dickie et al, 2014 and Pareek, 2017). The change in climate is conspicuous due to the visibility in the increase in atmospheric CO_2 concentration. The conditions of livelihood will even get worse in the regions like Asia & Pacific and Africa as about 40-50 % and 67 % of the total population of these regions are directly working in agriculture. The increase in global temperature is the root cause of climate change and it is caused by the two major factors namely climate itself and anthropogenic activities.

5.2.2 Climate change – contributing factors: Greenhouse gases (CO_2, CH_4 and N_2O) on the atmosphere and their variations are the cause of climate change. India's share of GHG emission to the total emission of the world is about 6.55 %, thereby becoming the third largest GHG emitter in the world (Sapkota et al, 2019). Both natural and anthropogenic activities are contributed to the emission of GHG worldwide. Burning of fossil fuel, transportation, deforestation is attributed to the man-induced influences on climate change. In India, the sectors such as Energy, Agriculture, Industrial process, land use management and wastes release about 68.7 %, 19.6 %, 6 %, 3.8 % and 1.9 % of Green House Gases (GHG) respectively to the climate change. Of the 19.6 % of the Green House Gas emitted from the agricultural sector, about 47 % and 45 % of the gases are released from the use of synthetic fertilizers and enteric fermentation respectively (WRI CAIT, 2017 as cited in USAID).

Cattle production is the most important factor in the GHG emission, followed by rice cultivation, buffalo, small ruminant and wheat production. Of the total crops cultivated in India, over 52 % of the GHG emission is from rice cultivation, followed by wheat, cotton and sugarcane, thus, these crops contributed about 80 % of the total GHG emissions of the total agricultural crops. In the livestock sector, cattle, buffalo, sheep and goat has contributed about 99 % of the GHG emission. The report of WRI CAIT shows that the agriculture emission of GHG increased by 25 % from 1990 to 2014. According to the parliamentary committee report, From 1970 to 2014, greenhouse gas emissions increased by 80%; 33 lakh tons of methane is released by paddy fields and 0.5-2 kg nitrous oxide is released per hectare (of paddy fields) (Mishra, 2019). The release of CO_2, Methane and Nitrous Oxide etc. are the primary causal agents of global climate change.

Agriculture plays a dual role in climate change both as a contributor to climate change and also mitigate the impacts of climate change through carbon sequestration. The cultivation of rice is responsible for the release of global warming gases such as CH_4 and N_2O coupled with burning of straw aggravates the warming of the earth. About 80 % of

straw is burned in India, especially after combined harvesting. The burning results in loss of soil nutrients such as N, P_2O_5 , and K_2O. In Punjab, paddy straw/residue burning caused a net loss of 4.5 billion INR (Gupta et al, 2004). Moreover, the excessive de-vegetation, industrialization, increasing pollution, use of chemical and fertilizers are significantly contributing to climate change (Rama Rao et al, 2018).

Table 1. Highest GHG emitting state crop wise

S.No.	Crop wise GHG emission	Highest emitting State
1.	Rice	Andhra Pradesh
2.	Wheat	Uttar Pradesh
3.	Sugarcane	Maharashtra
4.	Cotton	Uttar Pradesh
5.	Buffalo	Uttar Pradesh
6.	Cattle	Madhya Pradesh
7.	Goats and sheep	Andhra Pradesh

Source: Sapkota et al, 2019

5.3 IMPACTS OF CLIMATE CHANGE – INDIAN EXPERIENCE

In total, about 800 million people in South Asia would be prone to climate change scenario including India. GDP per capita in India is estimated to decline to 9.8 % by 2050 under carbon intense climate change, further, India may have to face a loss of 2.5 % GDP by 2050 due to climate change. Similarly, the climate change induced yield loss was estimated to be 4.5 to 9 % in India, which will lead to a loss of 1.5 % of GDP on an annual basis (Vijayan and Viswanathan, 2018). In India, central region states such as Chhattisgarh and Madhya Pradesh in a northern state like Uttar Pradesh, and northwestern regions like Rajasthan were identified to be more vulnerable to change in average weather parameter, thereby affecting agriculture, health and overall living standards of the population (World Bank, 2018).

In India, the loss of productivity and increase in food price are the two extremities of climate change, which could push about 42 million population additionally into the poverty trap and cause 0.4 % loss in overall consumption rates. India is likely to face around 10 % rise in cereal price and 3-4 % more poverty after 30 years than the present times due to rise in temperature and other weather parameters (Jacoby et al, 2011). Indian farmers might have to incur near about 3 % net income loss if the temperature rises by 2^0C and +7 % change in average precipitation (Kumar, 2011). Climate change may cost USD 9 to 10 billion every year. India might have to produce 70 million more food grains by 2030 to feed the growing population (The economic times, 2017).

5.4.1 Recent observations on climate change and its impact on agriculture the impact of climate change on the land mass/ biosphereis invariably linked to the production systems of crops. As the land is the pool house of Carbon, it can play a major role in the carbon cycle and increasing the crop yield. Climate has strong influences on soil

formation, development and its use. However, the chemical and physical properties of soil have been altering due to changes such as rise in temperature, variations in rainfall, increased evapotranspiration, drought, loss in Organic Matter Content, chronic loss in water holding capacity and nutrition availability. Therefore, affecting the growth and development of crops. These changes will lead to fluctuation in organic matter turnover and CO_2 cycle (Karmakar et al, 2016).

5.4.2 Temperature: The mean global temperature (combined land and ocean surface) was about 0.85^0C between 1880 and 2012 (IPCC). The global yield of wheat, rice, maize and Soybean will be reduced by 6 %, 3.2 %, 7.1 % and 3.1 % for every 1^0C increase in mean temperature. The annual mean temperature in India rises by 0.68^0C in every 100 years and India is continued to witness increased post-monsoon and winter warning (Kaur and Kaur, 2018). It is projected that temperature would rise to 2-4^0C in Southern India i.e. regions south of $25N^0$ and 4^0C in the northern regions (Kumar, 2011).

Box-3: Impacts felt everywhere

About 50 % of the farmers in Mahbubnagar district in the state of Telangana opined that the rate of unemployment has become severe during drought seasons. The severity of drought further forces the farmers to mortgage their productive lands to meet the basic needs. In the same way, farmers have been facing detrimental challenge to the education of children, food for self-consumption and socio economic support system as a result of emerging water disputes, out migration, etc.

Singh et al, 2017

India is likely to see 15-17% food grain reduction for every 2^0C increase in temperature. In Rajasthan, the yield of Pearl Millet is expected to be reduced to 10-15% at the 2^0C increase in temperature and in Madhya Pradesh, Soybean yield is expected to decline by 5% for about 2^0C increase in temperature. Therefore, the 2^0C increase in temperature might reduce the rice yield by 0.75 tons per ha. Similarly, increase temperature about 0.5^0C in winter may reduce wheat yield by 0.45 tons per ha (cited by Kaur and Kaur, 2018 and IPCC, 2007). The increasing temperature produces more heat stress to the crops. Yet, the magnitude of effects differs across the latitudes. For example, a 2^0C increase in temperature in the mid-latitude would increase wheat production by 10%. The heat and cold waves are the other extremities of the rising and decreasing temperatures in the tropical and sub-tropical/temperate regions, respectively. These waves are also a cause for a significant loss of crop production across the country, yet the magnitude of loss is lesser when compared to other climate extremities such as drought and flood. Moreover, the cold waves are the phenomena in the winter season across the length of the country.

5.4.3 Drought: Drought occurs from acute water shortage resulting from subnormal rainfall, erratic and uneven distribution rainfall coupled with ever-increasing temperature. IMD defines drought as a year or season in which the total rainfall is less

than 75 % of the climatological norm (or 30-year average). During 1900-2014, a large number of the Indian population have been affected from drought, which was more than any other natural disaster. Successful cultivation of crops is dependent on the nature of drought (chronic and contingent), its duration, frequency of occurrence within the season (Rao et al, 2016). Droughts can cause long term water shortage and heat stress to the crops, thereby affecting the yield (Conforti et al, 2017). A total of 38 % of the world area is exposed to droughts, which would impact the 70% of the agricultural output (Dilley et al, 2005). About 83 % of the loss caused by droughts was accrued to the agriculture sector during 2006-2016 (Conforti et al, 2017).

Box-4: A case of Marathwada Region – frequency of droughts

Marathwada region in Maharashtra state of India is vulnerable to climate extremities such as dry weather, deficient rainfall etc. During 2011 to 2015, the Marathwada region faced a total of 4 deficit rainfall years. The year 2011, 2012, 2014 and 2015 received a deficient rainfall of about 19 % (667.5 mm), 23 % (637.2 mm), 46 % (448.3 mm) and 59 % (336.7 mm) respectively against the normal rainfall (830.3 mm). The data showed that, every year the rainfall pattern deviates from its normal pattern as well as the year 2015 was recorded to be the prolonged dry spell, which lasted for more than 45 days. This resulted in severe droughts across the Marathwada regions. These dry spells affected the crops such as Soybeans, Pigeon Peas and a subsequent moisture stress had a negative effect on pod size, vegetative stages, and overall yield.

- Asewar et al, 2018

In India, failure of monsoon or reduction in rainfall leads to drought or drought-like conditions, which causes 18 % yield loss in unirrigated conditions (Economic Survey, 2017). About 60 of Indian districts were the most drought-prone and have less resilient areas. Only 10 states out of 30 states and UTs have at least 50 % resilient areas, the lower Himalayan region states such as Sikkim, Punjab, Haryana, Uttarakhand, Himachal Pradesh and Arunachal Pradesh have more resilient areas whereas, the states Karnataka and Kerala had less resilient areas. It is observed that the states with more forest areas/cover can exhibit more resilience than the states with other types of biomass (Sharma and Goyal, 2018).

Table 2. Frequency of occurrence of drought in India region wise

S.No.	Regions	Frequency of occurrence of drought
1.	Assam	Very rare once in 15 years
2.	West Bengal, Madhya Pradesh, Konkan, Bihar, and Odisha	Once in 5 years
3.	South Interior Karnataka, Eastern Uttar Pradesh, and Vidarbha regions of Maharashtra	Once in 4 years

4.	Gujarat, East Rajasthan, and Western Uttar Pradesh	Once in 3 years
5.	Tamil Nadu, Jammu and Kashmir and Telangana	Once in 2.5 years
6.	Western Rajasthan	Once in 2 years

Source: NRAA, 2013

5.4.4 Cold Waves: The cold waves in extreme cases could reduce the crop yield by 10-40 % in wheat, 10-15 % in winter rice, 25-30 % in pulses, 50-70 % in mustard seed 60-95 % in Amla (Samra et al, 2003). Importantly, pollen sterility is the major cause of the cold waves, thereby reducing the yield of crops to a greater extent.

5.4.5 Rainfall: In India, Kharif and Rabi seasonal rainfall have been reduced by 26 and 33 mm respectively between 1970 and 2015 (Economic Survey, 2017-18), meanwhile, annual rainfall was reduced by 86 mm in the same time period. The economic survey shows that the proportion of wet (rainfall more than 80 mm per day) and dry days (rainfall less than 0.1 mm/day) has become intensified between 1970 and 2015. About 15-40 % reduction in rainfall may happen in northern regions (NATCOM, 2004). Besides, the increased intensity of rainfall during the monsoon season has resulted in a severe flood in many parts of India. Delayed and early withdrawal of monsoon is reported by the farmers in the north and south zones of India (Rama Rao et al, 2018).

5.4.6 Floods: About 23 of 36 States / Union Territories of the country are flood prone, i.e. about 49.8 M. ha (15.2 %) of lands are subjected to flood. 10-12 M. ha of areas is flooded every year (Rao et al, 2016). Flooding has caused the serious damage to the crops worldwide and it is a more disastrous as the severity of damages can be observed in terms of damages to crops, water contamination, irrigation systems, livestock, other agricultural operations daily life etc. More than 50 % and 40 % of the farmers of East and North zones reported an increase in the frequency of flood in the recent past (Rama Rao et al, 2018). The lower Ganga basin is susceptible to flooding, even a small variation in rainfall pattern would affect the yield of crops grown in that regions (Gornall et al, 2010). During 1953-2010, the damages caused by the flood were estimated to be Rs. 8.12 trillion in India. Recently, in 2018, heavy downpour in Kerala state affected the entire state with the heavy flood and inundation. The "2018 flood" caused by the heavy downpour has been the worst flood since 1924. This flood took a high toll and estimated loss of 95, 000 million INR. The yield loss of Black pepper, cardamom, nutmeg, clove, ginger, turmeric was estimated to be about 25-55, 20-35, 15-25, 10-20, 15-25 and 10-15% respectively. The production loss of these crops was about 26 thousand tons during 2018-19, valuing about 12451.1 million INR (Thomas et al, 2018).

Table 3. Floods/ heavy rain affected areas and damages in India (1953-2011)

S.No.	Particular	Unit	Average	Maximum damage	Year
1.	Area affected	M. ha	7.2	17.5	1978
2.	Population affected	Million	32.4	70.5	1978
3.	Crop area affected	M. ha	3.7	12.3	2005
4.	Value of damage of crops	Rs. in million	11.2	73.0	2003
5.	Value of total damage to crops and public utilities	Rs. in million	36.1	325.4	2009

Source: Rama Rao et al, 2019

5.4.7 Water resources: The gross per capita availability of water is reducing on the account of two causes viz., climate change and population growth (Schellnhuber et al, 2013). The changes in precipitation, evapotranspiration and soil moisture under increasing temperature have a profound effect on groundwater resources (Singh and Kumar, 2014). Climate change induced changes in river flow and groundwater will have the serious of implications to the availability of irrigation water, thereby affecting millions of smallholders. India has only 1/25th of the water resource in the world whereas, every one in six the world population is Indian (Jat et al, 2016). According to FAO, on an average 87 % of water is used for agriculture in India. About 15 % of the groundwater resources in India are damaged due to climate change. The more is the variability of rainfall, the more is the change in the groundwater levels (Singh and Kumar). India has witnessed an 8 to 16 meters below ground level (m bgl) water depletion since 1980 (Zaveri et al, 2016). The effects of climate change on groundwater resources are seen in two ways viz., imbalance in the distribution of groundwater recharge and change in the volume of groundwater recharge (Singh and Kumar, n.d.). The subsidized power supply to farmers is one of the major reasons that led to the rapid extraction of groundwater for irrigation and the conditions have become induced under the adversity of climate change (Zaveri et al, 2016).

Table 4 Expected Crop Water Requirement in Wheat by 2050

S. No.	State	Area (ha)	Crop water requirement (mm)			water requirement (million cubic meter)			% Deviation (2020-1990)	% Deviation (2050-1990)
			1990	2020	2050	1990	2020	2050		
1.	J&K	253023	217.4	224.3	229.7	823.9	851.7	874.5	3.1	5.3
2.	HP	367770	281.8	291.8	299.1	1051.1	1089.7	1119.2	3.7	6.3
3.	Punjab	3468000	359.1	371.8	380.8	12553.6	13002.5	13317.5	3.6	6.1
4.	Haryana	2316674	452.1	467.1	480.9	10475.4	10825.4	11158.0	3.4	6.4
5.	UP	9443104	423.7	434.6	447.9	39717.8	40750.1	41990.4	2.6	5.8
6.	Bihar	2076727	438.6	449.3	465.0	9046.2	9271.1	9593.9	2.5	6.1
7.	West Bengal	366729	399.8	407.2	425.2	1449.5	1479.8	1543.1	1.9	6.4
8.	Rajasthan	2010241	485.3	498.6	511.6	9923.6	10208.4	10479.5	2.7	5.4
9.	Gujarat	727400	604.7	614.7	630.9	4603.3	4683.2	4807.1	1.7	4.3
10.	Madhya Pradesh	4188248	502.0	513.3	526.2	21176.9	21655.3	22200.1	2.3	4.9
11.	Maharashtra	932800	606.417	617.82	633.5	5613.8	5718.3	5859.4	1.9	4.5

Source: AICRPAM - CRIDA

Box- 5: The water risks hot spots in India

The states such as Punjab and Haryana account for about 15 % of rice and 29 % of wheat production in India (GoI, 2017). About 38 and 62 % of rice and wheat are procured from these two states in the country (OECD/ICRIER, 2018). The factors such as abundant river water, groundwater, which coupled with fertile lands are contributing to the high crop productivity. However, in the recent past, the need for irrigation water for these two states has become intensified due to vagaries climate parameters like change in precipitation, high inter seasonal and inter annual rainfall pattern etc. as a result, the groundwater table has been decreasing gradually. In 2010, the groundwater table in 75 % of the Punjab state fall below 15 m as against 14 % of the land mass of Punjab in 2000. Moreover, 51 % and 75 % of the local units of Haryana and Punjab were considered as "over exploited", in respect of water use in 2016. These phenomena coupled with intensifying pumping, over use of groundwater, etc., would further deepen the water tablet to a tune of 50 m in most parts of Punjab state by 2023 (OECD/ICRIER, 2018).

S.No.	Country	Crops	Reduction in Yield in 2060 (%)
1	USA	Corn	3
2	China	Rice	5
		Tropical cereals	6
		Pulses	3
3	Brazil	Rice	20
		Maize	16
		Pulses	20
4	Indonesia	Rice	20
		Maize	16
		Oil crops	20
5	South Africa	Pulses	12
6	India	Temperate cereals	15
		Rice	11
		Maize	10
		Tropical cereals	13
		Pulses	17
		Roots and tubers	21
		Oil crops	21

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groundwater table has decreasing gradually. In 2010, the groundwater table in 75 % of the Punjab state fell below 15 m as against 14 % of the land mass of Punjab in 2000. Moreover, 51 % and 75 % of the local units of Haryana and Punjab were considered as "over exploited", in respect of water use in 2016 (OECD, 2018). These phenomena coupled with intensifying pumping, over use of groundwater , etc., would further deepen the water tablet to a tune of 50 m in most parts of Punjab state by 2023 (OECD, 2018).

5.4.8 Incidence of pests and diseases: The increasing temperature may lead to increased metabolic activity in insect pests. Crop losses will be aggravated in the regions where increasing temperature contributes to the population growth of insects and their metabolic rates (Deutsch et al, 2018). In this context, the growth of the insect population will lead to increased herbivorous behaviour of insects which feed on crops, resulting in severe crop losses. The applied pesticides will be dissipated at rapid rates than under normal climatic conditions (Adults of Nezara viridula and Halyomorpha halys mortality rates may reduce by 15 for every 10^0C increase in temperature), the migratory insects would last for long in the suitable regions. Precipitation has its own impact on the insect population. For instance, the onion thrips and cranberry insect pests are sensitive to high precipitation, these insects may be removed when exposed to high rainfall (Kambrekar et al, 2015). Similarly, a few insects die in the drought-like conditions e.g. pea aphid. On the other hand, BHP populations show a mixed result of rainfall variations. For example, the incidence of BHP is more in the conditions of rainfall near about 400 ppm and is high when receives the rainfall more than 500 PPM (Kambrekar et al, 2015). Although the use of pesticides, GMOs and agronomic practices have been advocated and adopted by farmers to mitigate the impacts of climate change, the efficiency of these control measure would be minimal amidst climate-induced pest and diseases. The elevated CO_2 could cause the *Spodoptera litura* to feed more on its host plant.

5.4.9 Glaciers

Most of the glaciers fed river basins in the world are facing severe vulnerability due to change in climate systems. These melting ice and glaciers alter the hydrological systems, thereby affecting the quantity and quality of water resources (IPCCC, 2014). In India as well, most of the population are depended on glaciers fed river systems. Importantly, the rivers like Ganga, Indus, Brahmaputra etc., are glaciers based. The variations in climate might affect the river water flow and could deprive the water availability for both agriculture and human consumption.

5.5 RECENT OBSERVATIONS ON CLIMATE CHANGE AND ITS IMPACT ON ALLIED SECTORS

The livestock is equally suffering from climate change. Within the agricultural sector, 7 % of the livestock sector was affected by disasters including climate-induced disasters. The obvious effects of climate change/disasters on livestock are weakened body conditions and lowered animal productivity (Conforti et al, 2017). The diseases/pests of livestock are emerging/ migrating due to change in the climate. Bluetongue a disease which affects sheep and to some extent affect the goat and cattle are spreading from tropics to mid-latitudes. The mortality rate of livestock is increasing due to a rise in temperature. In tropical countries, the mortality rate is even severe. The outbreak of Foot and Mouth Disease (FMD) in cattle was observed in Andhra Pradesh and Maharashtra to the tune of 52 and 84 % due to temperature, humidity and rainfall; Mastitis incidence increases in dairy animals during hot and humid weather, in turn, increases the flies and tick (National Intelligence Council, 2009).

Heat wave can reduce milk yield by 10-30% in first lactation and 5-20% in second and third lactation periods in cattle and buffaloes it also affects the growth, puberty and maturity of crossbreed of cows and buffaloes (NPCC 2004-07). The average weekly and monthly milk yields were reduced by 0.062 and 0.069 kg respectively for a % rise in relative humidity (Das, 2017).

The physiological conditions of cattle such as rectal temperature and respiration rate were increased significantly per unit increase in air temperature, Relative Humidity and Temperature Humidity Index (THI). The fertility of dairy cows is reduced due to heat stress, besides, the heat stress reduces the estradiol secretion, thus increasing the interval of calving period. In the same way, heat stress would affect the growth of fetus due to the decreased blood supply to the uterus, thereby causing the placental insufficient to provide maternal nutrient (Das, 2017).

In the summer the conception rate of cows may reduce up to 20-27 % (Sejian et al, 2016). On the other hand, increasing average minimum and maximum temperature are affecting the sperm concentration in bulls, thereby causing low ejaculation volume in summer than winter. The increasing temperature will further impede the availability of fodder and feed to the livestock, further, the formation of lignin content in the fodder and plant tissue due to high temperature could decrease the digestibility of livestock (Das, 2017).

Annual enteric fermentation emission from India is about 10.27 TG. The methane emission is high among indigenous cattle breeds (48.5 %) than crossbred or other livestock. Average methane emission for lactating animals was about 53.6 g CH4/kg milk (FAO**)**. The milk yield of Holstein, Jersey and Brown Swiss was about 93, 97 and 98 % at a temperature of 29^0C and relative humidity of 40 %, whereas the yield of theses cows

reduced to 69, 75 and 83 %, respectively when exposed to the relative humidity of 90 % (Berman, 2005). The incidence of diseases are reported to be high among livestock, the hot weather climate causes clinical mastitis in dairy animals. The increase in cattle ticks such as *Boophilus microplus*, *Haemaphysalis bispinose* etc. are reported across the country due to hot humid weather conditions (Das, 2017).

Above 30^0C, the feed and energy intake of poultry birds decreases causing a decline in production and the rising temperature could decrease the digestibility of nutrients in poultry, thereby affecting the nutrient supply to egg production, egg mass and shell quality of egg in layers and growth in broilers (Das, 2017). Fisheries have also been impacted by the changing climate. The biological process and marine food systems are subjected to severe stress due to change in the climate. The factors such as warming of sea surface temperature, increased intensity of temperature, alternate current systems of seawater etc. coupled with overfishing and anthropogenic activities could impact the fish production systems across the globe (Lu, 2011). According to the Ministry of Agriculture, the milk production could decrease by 1.6 metric tons by 2020 and by 15 metric tons by 2050.

5.6 Mitigation and adaptation towards climate smart agriculture: Climate smart practices and production technologies will help the farmers to mitigate the emission of GHG emission and adapt agriculture to the emerging agrarian issues of climate change. According to Sapkota et al, 2019, GHG emission from agriculture would be 489 $MtCO_2e$ by 2030 without any mitigation measures. However, the emission of GHG would be curtailed to 410 $MtCO_2e$ with the mitigation and adaptation. i.e., technical mitigation has the potential of 78.67 $MtCO_2e$ per year, while, the restoration of degraded lands would enhance the mitigation potential up to 85.5 $MtCO_2e$ per year.

5.6.1 Climate smart seeds/ breeds: Climate smart seed/variety development encompasses a range of practices, which include conservation of plant genetic resources, the involvement of stakeholder in production, multiplication, processing, storage, distribution, marketing and dissemination of seeds/ improved varieties, etc. (Lipper et al, 2014).

The key role of conserving the traditional seed varieties and using them to build a climate resilient cropping systems was adopted by the policymakers from across the landraces have become one of the climate adaptive strategies followed by the agricultural stakeholders in a changing climate. However, lack of availability of quality and improved seeds are the major challenge to the adoption. Most of the farmers in India have adopted the drought and pest tolerant as well as short duration crop varieties. About 80 % and 70 % of the farmers in North and south zones suffered from non-availability of improved seeds. For Example, KVK, Jalna has introduced several climate smart varieties in Kadegaon village of Jalna, Maharashtra to mitigate and adapt agriculture to climate change. The varieties such as BDN – 711 (Pigeon Pea-short duration rainfed variety), MAUS-71 (Soybean- non shattering and high yielding variety when cultivated on Broad

Bed Furrow), Netravali -1415 (Wheat-Heat and low water requiring variety), Parbhani Moti (Rabi Sorghum-suitable for rainfed condition in Rabi season) and Digvijay (Bengal Gram-suitable for both rainfed and irrigated areas) recorded increased yield than conventional variety grown by the farmers in Kadegaon village of Jalna (Sonune and Mane, 2018).

In Heeranar village of Dantewada, KVK, Dantewada has demonstrated climate smart varieties such as Indira Barani Dhan-1 (short duration paddy varieties – suitable to reducing number of rainy days), Indira Ragi – 1 (Blast tolerance Ragi variety), Arka Rakshak (A tomato variety resistant to Bacterial and leaf curl), and TAU-2 pulses (Narayan et al, 2018).

Box-6: The flooding and the submergence of paddy – A case of Rayapuram in Tamil Nadu

A sudden down pour is the major exhibit of climate change. Tiruvarur district of Tamil Nadu has frequently been affected by intensive downpour of North East Monsoon in the recent past, resulting in drowning of paddy for a period of 10-15 days. The paddy varieties such as ADT 38, ADT 46, Co 43, TRY 3 and CR 1009 grown by the farmers of Tiruvarur district, in particular Rayapuram village are susceptible to flooding. As a result of which, farmers lost about 75 %of yield and total straw. Therefore, the changes in normal precipitation brought by climate change need to be offset by appropriate technology and extension advisory services related to flooding. The Krishi Vigyan Kendra (KVK), Tiruvarur has created awareness among farmers about the flood tolerant varieties such as CR 1009 sub and Swarna, sub 1 and has demonstrated the package of practices. Yet, KVK focuses mostly the National Innovation on Climate Resilient Villages (NICRA) adopted village like Rayapuram in the district. Thus, the appropriate climate funds, manpower, climate advisory models need to be strengthened to the diffusion of the flood tolerant varieties across the district. In the same way, the traders and consumers need to be informed about the salient feature of newly introduced varieties, which could facilitate the tradability of the new varieties and sustain the income of the farmers.

-Ramesh et al, 2018

Breeds

For example, KVK, Dantewada is promoting Kadaknath poultry in backyard condition and to enable the farmers to earn additional income. It was reported that a unit of 50 birds could result in net income of Rs. 42,300, whereas, the net income from Broiler is only about Rs. 3,850. The rearing of Kadaknath has a B: C ratio of 15:67. On the other hand, B: C ratio for broiler rearing is not more than 2 (Narayan et al, 2018). The indigenous cattle breeds such as Sahiwal and Deoni have the high yielding potential under heat stress than Jersey and Red Sindhi Crosses (Das, 2017).

Rice + fish + vegetable farming system as a way to overcome the impacts of

5.6.2 Input smart: Input management has become a crucial part amid changing climate. The inputs right from fertilizer application to plant protection measures can have a positive effect in negating the impacts of climate change. The fertilizers such as slow release fertilizer, nitrification inhibitors etc., could be chosen as the way of moderating the release of global warming gases by agriculture (Dickie et al, 2014). Site specific nutrient management, soil test based fertilizer application, deep placement of urea, fertigation, leaf colour chart for rice, slow release fertilizer etc. application of composting prepared from the farm wastes, compressed cakes of plant material and flower as manure, etc. Similarly, application of Mahua (*Madhuca indica*) cake, neem (*Azadirachta indica*) cake and Karanj (*Derris indica*) cake along with the Farm Yard Manure (FYM), application of Acetyl alcohol to reduce the evaporation from farm ponds, application of KNO_3 in cotton and soybean, etc. are good input management strategies to mitigate the climate change effect on crops.

Adoption of precision nutrient technologies coupled with the reduced Nitrogen consumption has the mitigation potential of 17.5 $MtCO_2e$ per year and could save about Rs. 65000 per tCO_2e abated. However, the fullest adoption of precision application of fertilizer needs changes in policy measures and efforts by farmers. In India, the subsidized urea has become the cheapest source of N, thus, Urea accounts for 82 % of the total consumption of N in India and mostly it is applied by broadcast method, rusting in the direct and indirect release of GHG emission (Sapkota et al, 2019).

5.6.3 Climate smart cropping management: Conservation tillage/no-tillage, crop rotation, contingency planning, changing the cropping calendar, use of trap crops, low water consuming crops, etc. are a vital part of cropping management. Crop diversification, Integrated Farming System, agro-forestry etc., have also been advocated as a part of climate mitigation options. Rice, fish and vegetable farming under Sunken and raised bed system has led to an increase in net income from farming. The average net income is calculated to be 1.2 lakh per ha. This farming system has a B: C ratio of 4.78. Similarly, the cropping systems such as fruit crops & vegetables; fruit crops & pulses, tree crops (e.g. neem trees) + pulses etc., have been promoted to mitigate the impacts of climate change.

The cultivation of climate smart crops such as Jowar, Maize and other minor millets could withstand the negative impacts of climate change as these crops are hardy, suited for semi-arid and tropics. For example, the rise in temperature has not altered the yield of Jowar in Andhra Pradesh from 1986 to 2010 (Padakandla, 2016). Changing the cropping pattern is often seen as one of the most desirable climate smart practices adopted by the farmers in India. This practice is most common among the farmers in the drylands tracts of India. In Karnataka, about 25 and 82 % of the farmers in Gundlapalli and Saddapalli

villages respectively of Bagepalli block (Chikballapur district) have changed their cropping pattern to mixed cropping to avoid climatic risks (Katutura et al, 2015).

Table 5. Climate smart cropping management

S.No.	Climate Smart cropping management	Impact	Author
1.	Maize (cultivar. Nilesh) intercropped with cowpea (cultivar. Hariyali Bush) under reduced tillage followed by mustard crop cultivation	This cropping system has a maize crop system productivity up to 200 % and 230 % net profit under this system in the rainfed areas (India)	Pradhan et al, 2018
2.	The shift of cropping pattern from food crops to vegetables and commercial cropping under increased adversity of climate change	90 of the farmers in two villages of Nasik district (Maharashtra) have shifted the cropping pattern to grapes, sugarcane along with the production of vegetables and fruit orchards. The farmers in Guntur district of Andhra Pradesh reported that the paddy cropping area has reduced to 20 % from 50 % in the last 2 decades and was replaced by the chillies and wood plantations. On the other hand, horticultural crops have been promoted by the stakeholders of agriculture including the department of agriculture to overcome the future possible climatic risks. In the state of Karnataka also, farmers have shifted from water-intensive crops (paddy) to low water-intensive crops.	Banerjee, 2015, Kattumuri et al, 2015
3.	Crop diversification	Crop diversification can surpass the pests and disease outbreaks under climatic risks, particularly, it provides income stability. Likewise, crop diversification with agroforestry was found to have higher organic soil stocks. Crop diversification towards horticultural crops has become more prominence in southern and western parts of India. In Saddapalli village (Chikaballapur district, Karnataka), 97 % of farmers have diversified their	Kattumuri et al, 2015

		cropping pattern from groundnut to drought-resistant horse gram and maize.	
4.	Agroforestry	Agroforestry is gaining momentum owing to its capacity to generate additional income to the farmers. In Saddapalli and Gundlapalli villages in (Chikabalapur district, Karnataka), farmers have adopted at least three crops to provide sustainability to the farming. The tree species such as neem, Pongamia, coconut, mango, tamarind, custard apple, banana, drum stick, jack fruit, acacia, Syzygium, and pomegranate were planted by the farmers. Benbi et al found that wheat – rice – agroforestry cropping system has the potential to sequestrate about 65-68 % of the organic carbon stock in semi-arid regions of India.	Kattumuri et al, 2015 and benbi et al, 2012

5.6.4 Water/ soil smart: Around the world, different water-smart practices and technologies have been developed and disseminated to enhance the productivity of crops under climate stress. A range of adaptation options are available to improve the resilience of agriculture to water stress, which ison-farm water storage, watershed development, modernizing irrigation infrastructure, on-farm irrigation management (Drainage, alternate wet and dry etc.,), reallocation of water, protective irrigation etc. the use of micro irrigations is expected to enhance the irrigation water use efficiency by 90 % (Lipper et al, 2017).

Zero tillage has been adopted as a soil and water conservation practice. Zero tillage has immense potential to increase the yield and reduce the cost of cultivation. Similarly, vegetative barriers, Conservation Bench Terrace, Peach Based Agri-horticultural Practices etc., have been followed in Uttarakhand and Himachal Pradesh states in India (Bhattacharyya, et al, 2016). The constructions of small ponds called Doba water harvesting structures have become famous in Jharkhand state. The size of the doba structure may be of 3x2x1 m^3 and has the capacity to withhold 4.5 m^3 of rainwater and the inner structure of Doba is lined with the black polythene sheet. Once the rainwater is received into the structure, and it is covered with the thatch, which is available locally. It was found that these structures were helpful in providing lifesaving irrigation to the establishment of the orchard (Dey and Sarkar, 2011).

In Central India (Madhya Pradesh), the water conserving practices like Broad Bed furrows (BBF) has resulted in 35 % increase in yield in Soybean and 21 % increase in yield soybean, 30 % in Maize and 16 % in wheat. The conservation furrows have also had a greater impact on the yield (up to 15-20 %) soybean, maize and groundnuts (Alfisol) in the state of Karnataka when compared to farmers practice (Bhattacharyya, et al, 2016). In Kyrdem village (Meghalaya), KVK, Ri Bhoi has demonstrated the importance of Jalkund for cultivating vegetables in lean season through NICRA. About 12 Jalkund (5x4x2 m^3) with the capacity of storing 40, 000 liters of water was established in Kyrdem village. In this way, about 4.08 ha of lands were brought under vegetable cultivation by the farmers. In addition, the cropping intensity has increased 204 % in Kyrdem village (Medhi et al, 2018). In Tumkur, the demonstration of trench cum bunding in the NICRA project villages has decreased the soil erosion and increased the retention of soil moisture for a longer period of time. This intervention has increased the Finger Millet yield by 27 % (Jasna et al, 2014).

Box-7: Water smart climate adaptive technology – A case of Dry converted wet rice method in Telangana region, India

Innovations in water saving crop production technologies have become an essential part of climate smart agriculture. Most of the Indian states started experiencing the deficit rainfall in past decade. The dry land tracts of India have become more prone to deficit or delayed monsoon than ever before. Telangana state in India has also suffered heavily from delayed or failure of monsoon. More often, in Khammam district of Telangana state, the farmers' practices of transplanting of rice has severely been affected in the recent past due to water shortage/non availability of water during transplanting as well as the transplanting of rice has further deprived the water resources. Therefore, Krishi Vigyan Kendra in Wyra, Khammam district has prompted **Dry converted wet rice** method as an alternative to transplanting. This method has proven to have leveraged the water requirement and reduced the labourer need. This method has hugely benefited the farmers as this method does not require nursery raising, pulling, transporting seedlings and transplanting since the rice seeds can directly be sown using seed dill on a well-levelled field. The assessment of this method shows that about 40-50 % of water can be saved compared to the transplanted method. In addition, dry converted wet rice matures 7-10 days earlier as compared to transplanted crop. Presently, in Khammam district, the area occupied under Dry Converted Wet Rice is more than 6000 ha. Further, the adoption of this method has led to a 30 % (Rs 15,500 ha^{-1}) reduction in cost of cultivation.

The Benefit: Cost ratio of Dry converted Wet Rice is about 2.49, whereas the B: C ratio in transplanted rice is only 1.78. Furthermore, the extension functionaries of KVK have persuading other rice growers to adopt the technology and to mitigate the dwindling water resources caused by climate change.

- Hemantha Kumar et al, 2018

Heeranar village, Dantewada district (Chhattisgarh state), KVK, Dantewada has renovated two old stoops dams, five open wells. These renovations have led to an increased cropping intensity from 105 % to 116 %. Similarly, the productivity of rice and green gram was increased by 21.79 and 24.93 % respectively owing to the longer availability of water for irrigation. Farmers have also started cultivating vegetables throughout the year under the *Wadi* System. On the other hand, creation farm ponds, percolation ponds have enabled the farmers to increase the area under rice and vegetable cultivation. It was recorded that the yield of rice and vegetables increased up to 21.33 and 35.69 % respectively (Narayan et al, 2018).

Table 6. Mitigations and adaptations in soil and water conservation

S.No.	Water/ Soil smart	Impact	Author
1.	Contour bunding	Contour bunds are capable of reducing the soil erosion, the areas with the contour bunds have reduced the soil loss by 0.3 t/ha from 18.92 t/ha.	Mishra and Triupathi, 2013
2.	Zero Tillage	Zero tillage has high water and fertilizer use efficiency when compared to conventional cultivation. It is estimated that farmers can reduce the input cost by 41 % and increase the yield by 6 % under zero tillage. In Indo Gangetic plains, the adoption of zero tillage in wheat-rice systems has provided the additional income of Rs. 6,951 per ha. When zero tillage combined with the adoption of improved seeds practiced in the wheat-rice system in Indo Gangetic plains, it has the potential to generate the net returns up to Rs. 15, 303 per ha. Besides, adoption of ZT in rice, wheat, cotton and sugarcane would abate the GHG emission of 15 $MtCO_2e$ per year and save the cost of Rs. 42000 per tons of CO_2e saved.	Khatri-Chhetri et al, 2016 and Sapkota et al, 2019
3.	Watershed management	Watershed development often adopted as a way to address the problems of rainfed areas in the country. according to Bhattacharyya et al, the benefits of watershed programmes include augmented income, rural employment generation (151 person days ha´1), increased crop yields and cropping intensity (36%), decreased runoff (45%) and soil loss (1.1 t¨ ha´1 ¨ year´1), augmented ground-water and	Bhattacharyya, et al, 2016) and Joshi et al, n.d.

		decreased poverty). Besides, the effectiveness of watershed development is dependent on the rainfall pattern.	
4.	Conservation furrows in Soybean	The demonstration of conservation furrows (Soybean) in Babhulgaon and Ujalamba NICRA villages, Marathwada (Maharashtra) helped the farmers to increase the yield, net returns and RWUE on average of 1502/ha, 22571/ha and 3.19Kg/ha/mm respectively in five years (2011 – 2015) under delayed on a set of monsoon. Besides, adoption of conservation furrows in intercropping of Soybean and red gram has additional yield and RWUE with 1650 kg/ha and 3.83 Kg/ha/mm. the average net return form the intercrop is about Rs. 31456/ha	Dr.B.V. Asewar All India Coordinated Research Project for Dryland Agriculture VNMKV, Parbhani, (M.S.)
5.	Maize-based production systems as conservation agriculture production systems	In the upland areas of Odisha, the grain yield of mustard and horse gram has increased to 25 and 37 % respectively, when grown after Maize intercropped with cowpea. Moreover, the residue retention of mustard in the field had a beneficial impact on productivity and net benefits.	Pradhan et al, 2016
6.	Mulching	Mulching plays a vital role in the conservation of moisture and controlling weeds and further spread. In Kyrdem village (Meghalaya), KVK, Ri Bhoi has helped the farmers to adopt mulching in ginger and turmeric on raised beds across the slope. About 40 farmers' field was demonstrated with the importance of mulching. It was found that the mulching has increased the income by 2.56 times in Ginger and 2.67 times in Turmeric. Besides, there was 30-35 % and 60-65 % reduction in weed growth and soil erosion respectively. In terms of yield, after the mulching/intervention, the yield of Ginger (Var. Nadia) has increased to 250 q/ha from 85 q/ha. Similarly, the yield of Turmeric has increased to (Var. MT1) to 310 q/ha from 225 q/ha. The BCR ratio of Ginger has increased to 2.70 from 1.70 after mulching	Medhi et al, 2018

		intervention, while, the BCR ratio of Turmeric has increased to 2.81 from 1.74.	
7.	Laser Land Levelling (LLL)	The adoption of Laster Land Levelling by the farmers in Indo Genetic plains has made a significant impact on high net return. The use of LLL in Wheat – Rice system has increased the net income to Rs. 8, 1119 per ha per year. Moreover, the adoption of LLL in rice-wheat cropping system would abate the GHG emission by 4 $MtCO_2e$ per year and save about Rs. 1940 per year for every tonne of CO_2e saved.	Sapkota et al, 2019
8.	Micro-irrigation	Water management practices such as sprinkler, drip irrigation and fertigation together may abate the GHG emission up to 5.5 $MtCO_2e$ per year. The key benefits of the adoption of micro irrigation include water use efficiency (50-90 %), expansion cropped area, the introduction of new crops, electricity saving up to 30.5 % due to the small power units etc.	OECD/ICRIER, 2018 and sapkota et al, 2019
9.	Happy Seeder	The application of happy seeder in Punjab regions has reduced the air pollution because the happy seeder allows the farmer to sow the wheat seeds without burning the stubbles of paddy.	Groot et al, 2019
10.	Organic farming	Organic farming lowers the N_2O, and CO_2 emission and increases the Soil Carbon Content. Enhances the biodiversity and soil microorganism, minimizes the indiscriminate use of pesticides, enhances the fertility of the soil, and promotes the use of soil, water and air in a healthier way.	Sartaj et al, 2013

5.6.5 Policy and Program smart: Polices play a crucial role in minimizing the impacts of climate change. Climate smart policies have become a central state with the convention on the United Nations Framework Convention on Climate Change (UNFCCC). UNFCCC was come into being in 1992, which aimed at reducing the risks of Climate change and to adapt to the future uncertainties of climate change. Kyoto Protocol-11th December 1997, Kyoto, Japan- legal binding established for industrialized Nations to reduce the emission of six GHG's (CO_2, CH_4, NO_2, Sulphur hexafluoride, hydro fluorocarbons and Per fluorocarbons) 5.2 per cent reduction during 2008-2012 from1990 emissions. An arrangement under the Kyoto Protocol allowing industrialized countries with a GHG's

reduction commitment to invest in ventures that reduce emissions in developing countries as an alternative to more expensive emission reduction in their own countries-Base year 1990. The long-term goal of the Paris agreement is to keep the temperature rise well below 2^0C from the pre-industrial level.

In most of the states, the major policy interventions like The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA, 2005) undertake the climate resilient activities such as the creation of mini watershed areas, water conservation, excavation/renovation of reservoirs/ponds, other rainwater harvesting structures, tree plantation and maintenance, etc. Thus, the scheme like this could enhance the resilience of agriculture and allied sectors during severe droughts and other climatic risks (Udmale et al), 2014. The farmers in Saddapalli and Gundlapalli villages, Chikabalapur district in Karnataka state have joined in MGNREGA after the crop loss resulted from the vagaries climatic conditions. It is reported that 82 of the households in these villages have gained employment opportunities from MGNREGA. Most of them were employed during the winter season. Thus, the scheme has provided a substantial income to the farmers in these villages, which compensated the income loss from agriculture due to climate change (Kattumuri et al, 2015).

Most often, policies of climate change aimed at mitigation and adaptation mechanisms. Policies are complementary to the adaptation processes, which include Research and Development, Capacity Building, Risk Aversion, Infrastructure and Funding Mechanism (Ignaciuk, 2015). A number of insurance policies are devised and implemented to avert the risks posed by climate change. The government of Maharashtra signed the Maharashtra Project for Climate Resilient Agriculture agreement with the World Bank with the help of the government of India. An amount of 420 million US dollar will be given by the International Bank for Reconstruction and

Box-8: National Mission on sustainable agriculture - India's National Action Plan on Climate change

India's National Action Plan on Climate change was implemented in 2008 with the eight sub schemes viz., (i) National Solar Mission, (ii) National Mission for Enhanced Energy Efficiency, (iii), National Mission for Sustainable Habitat, (iv) National Water Mission (v) National Mission for Strategic Knowledge on Climate Change (vi) National Mission for Sustainable Agriculture, (vi) National Mission for Green India and (viii) National Mission for Sustaining the Himalayan Ecosystem

The National Mission of Sustainable Agriculture (NMSA) was launched in 2013 with the focus on soil and water conservation, water use efficiency, soil health management and rain-fed area development. A number of programmes, climate smart initiatives, schemes have been integrated and mainstreamed into NMSA, which include System of Rice Intensification (SRI), the National Initiative on Climate Resilient Agriculture, Parampragat Krishi Vikas Yojana (PKVY), Pradhan Mantri Krishi Sinchai Yojana (PMKSY), National Food Security Act, 2013, Pradhan Mantri Fasal Bima Yojna (PMFBY) et., these sub components of NMSA encompass various climate related activities. Yet, the policy gives more emphasis to Rainfed Area Development (RAD),

which covered about 12 thousand ha of Integrated farming system, about 28 thousand ha of livestock based farming system, about 46 thousand of water harvesting and management structure (tanks, community water harvesting ponds and so on), etc. during 2018-19. Similarly, 1,751 trainings and 456 demonstrations were done under RAD of NMSA.

- GoI, 2017-18 (https://nmsa.dac.gov.in/RptActivityAchievement.aspx)

Development (IBRD) to implement the project, the project will benefit about 25 million small and marginal farmers in the areas of Marathwada and Vidarbha regions of Maharashtra. Also, it encompasses serious activities, which include on the farm and off-farm watershed development programmes, dissemination of climate resilient technologies such as micro-irrigation systems, expansion of surface water storage system, facilitation of aquifer recharge, popularization of climate resilient seed varieties (e.g. drought, salt, heat-tolerant varieties). Likewise, the emphasis is given to enhance the capacity of farmers' Organisation such as local farming institutions, Farmers Producers Organisations, Agri-enterprises, thereby ensuring the timely agro advisories and extension services to overcome the climate risks (PIB, 2019).

Box 9 National Mission on sustainable agriculture - India's National Action Plan on Climate change

India's National Action Plan on Climate change was implemented in 2008 with the eight sub schemes viz., (i) National Solar Mission, (ii) National Mission for Enhanced Energy Efficiency, (iii), National Mission for Sustainable Habitat, (iv) National Water Mission (v) National Mission for Strategic Knowledge on Climate Change (vi) National Mission for Sustainable Agriculture, (vi) National Mission for Green India and (viii) National Mission for Sustaining the Himalayan Ecosystem

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-GoI, 2017-18 (https://nmsa.dac.gov.in/RptActivityAchievement.aspx)

5.6.7 Extension/ knowledge smart: The first step towards, adaptation measure to climate change is bringing desirable change among farmers. A number of factors influence the behaviour of farmers, which include externals and internals. Externals such as subsidies, climate finance, incentives, extent of participation, linkages with the stakeholders relationship with fellow farmers, friends, neighbours and internals such as education, knowledge, awareness, attitude, education, farm size, family income, family labour on agriculture, etc. for which, extension advisory services play a major role

Climate smart technologies have become knowledge-intensive, hence, these knowledge-intensive technologies pose considerable challenges to farmers regarding adoption and continued adoption in the absence of relevant extension and advisory services, the adoption of climate smart technologies would be trivial (Hellen et al, 2014). In order to respond to climate change, a range of extension mechanism to be kept in mind. These extension modalities include indigenous knowledge, farmers collectives, climate training, Plant Health rallies, Climate Famers Field School, Participatory crop planning, the establishment of plant clinics, climate manager, monsoon manager, climate awareness campaigns, climate finance, incentives at farmers level (Rupan et al, 2018).

Access to climate information and awareness about climate-associated risks in agriculture are an essential part of mitigation and adaptation. A number of initiatives have been taken by agricultural stakeholders across the globe to address the risks and impacts of climate change. Access to climate information has become a crucial part of farm level decision making regarding adaptation. Capacity building programme has greatly impacted the adaptation practices of farmers in the Nagarjuna Sagar Project Command Areas. The practices include Alternate Wetting and Drying (AWD) in rice, Modified System of Rice Intensification (MSRI) and Direct Seeding of Rice (DSR). The capacity building helped the farmers to increase the rice yield. Agro met Advisories of CRIDA, are the bulletins prepared and disseminated to the farmers, the bulleting includes weather events for the past, present and future (at least 5 days ahead), stage wise information of crops and related farm activities or production practices to be taken up to mitigate the impacts of future weather changes. For example, the number of farmers in Bijapur districtwas benefited from the advisory services and by adopting right practices advocated through Agromet bulletin. The Studies found that farmers with better access to the agrometeorological services have increased the farm income.

Table 7. A few examples of farmers who have benefited from Agromet Advisories

S. No.	Farmer & Village	Forecast provided	Forecast used for	Benefits/savings
1.	Mr Shivaji Dege, Aheri	No rainfall in next 3-4 days	Spraying was deferred	Saved one spray costing Rs.4000/- per acre.

2.	Devanayak, Honawad	Rainfall expected within 24 hr.	Immediate spraying for disease	Saved losses to the extent of Rs, 60,000/- per acre. Non Adaptors incurred loss.
3.	Shivalingappa Marebaddi, Mugalkhod	Chances of rainfall after two days	Immediate Harvest of soybean	Got Rs. 1900/- per quintal against 1400/- of others who harvested after a rainfall event

Source: Annual Report, AICRPAM

Various ICT supported climate extension services have been implemented by a variety of public and private institutes. The establishment of ICT hubs and Village Access Centre by ICRISAT at Addakal block has been a successful ICT initiative amid climate change. ICRISAT with its core partner Adarsha Mahila Samaikya (AMS), a federation of women Self-Help Groups (SHGs) in the block identifies a group of Village Network Assistant (VNA), in order to disseminate the climate information and adaptive strategies based on the farmers' quarries. In India, block-level weather forecasts are provided to farmers in 25 NICRA districts. KVKs/Programme Coordinators are disseminating the capsule of weather forecasts along with crop advisory to prepare and to respond to the weather forewarning.

The multiple communication channels viz., mobile text, SMS, Voice messages, display at commonplace, personal contact etc., are used to disseminate the information. Notably, Field Information Facilitator (FIF) employed at micro/village level collects the real time field situations of crops, growth stages, pest and disease incidence etc., and send to KVKs. KVKs prepares crop advisories based on the field information collected from FIF and weather situation from IMD and crop advisories are communicated to the farmers by FIF. Micro-Level Agromet Advisory Services (MAAA) have helped the farmers to respond to climate change in advance, thereby avoiding the risks posed by climate change (Vijaya Kumar et al, 2017). Real Time Contingency Planning has also gained momentum in India. RTCP helps in overcoming agrarian issues such as the delayedonset of monsoon, seasonal droughts and floods (Rao et al, 2016). The impacts of Real Time Contingency Planning have been conspicuous throughout the country.

Table 8. Change in weather and advisory services; their impacts

S. No.	District/ state	Crop	Weather aberrations	Contingency measure	Yield (Kg/ha) With RTCP	Yield (Kg/ha) Without RTCP	B:C Ratio with RTCP
1.	Hoshiarpur (Punjab)	Pearl millet	Delayed onset of monsoon	Drought tolerant variety – FBC-16	4300	3400	2.89
2.	Lakhimpur (Assam)	Potato (Kufri pokhraj)	Early season drought in rainfed areas	Supplementary irrigation of 9.4 cm during stolon formation and tuber growth stage	26750	12100	Up to 3.87
3.	Indore (Madhya Pradesh)	Soybean	Mid-season drought in rainfed areas	Foliar spray with Mo@0.1 % in 2 sprays	412	399	2.03

Source: Rao et al, 2016

5.6.8 Energy Smart: Manure management is an important source of GHG emission in India. However, the establishment of biogas plants may mitigate GHG. In order to increase the establishment of biogas plants, the appropriate incentives and funds are essential. Similarly, cultivation of bioenergy plants needs to be promoted in the degraded lands, which not only help in carbon sink but also meet the bioenergy need of the burgeoning population. Moreover, biochar and bio gas production, solar pump sets, conversion of waste lands into greenery and energy smart activities can be promoted.

5.6.9 Institutional smart: A number of institutional arrangements such as, farmers groups, Panchayats institutes, commodity groups, value addition groups, Custom Hiring Management Committee, seed banks, fodder banks, farmers collectives for inputs management and marketing, etc. play a crucial role in mitigation and adaptation. Managerial and institutional innovations are more likely to play an important role in dealing with the impacts of climate change. Village Climate Risk Management Committee (VCRMC) has been established under NICRA across the country.

Box -9: Custom Hiring Centre

Use of machinery has become more among the farmers. In Dantewada, KVK under NICRA project has established CHC, which has the farm machinery such as power tiller, ridge maker, treasure, reaper, seed cum ferti drill, paddy transplanter, land leveller, cono weedier, and sprayer. It was found thatfarmers have increasing using the machinery. The use of power tiller, seed drill, thresher and paddy transplanter could result in savings of 70-75 % of labour cost. Similarly, 40-45 % of the labour cost can be saved wit the use of cono weeder and wheel hoe. The rent fee charged from farmers is deposited in the bank account of VCRMC. (Narayan et al, 2018)

VCRMC consists of 12-20 members; representing all sections of the community with at least 2-3 women members, elected/selected President, Secretary and Treasurer, VCRMC has to open a bank account operated by any two (President, Secretary and Treasurer), each transaction of money withdrawal to be accompanied by a resolution, sources of revenue, proceeds of CHC, contribution of community towards interventions. The water use institutions or associations such as Participatory Irrigation Management (PIM) and Water Use Associations (WUAs) are instrumental in augmenting the efficiency of water usage (Dev, 2018). There are about 56, 539 WUAs managing 13.16 m.ha of irrigated lands (NITI Aayog, 2015).

5.6.10 Allied sectors smart: The climate smart practices of livestock should provide an ambient environment to improve the production of milk, meat and wool. A number of allied smart practices have been adopted by the farmers across the country, which include shades for livestock (improves productivity and milk yield); grazing at night hours for 2-3 hours; increasing the concentration of minerals in feed (1.5-16 % of DM of potassium, 0.5-0.6 % DM of Sodium) have the potential to improve milk yield under heat stress conditions, 6g/cow/day of niacin would increase the milk yield; 150-200g/cow/day Sodium bicarbonate helps in buffering the rumen during hot conditions); the technology like Embryo Transfer Technology (ETT) enhances the reproduction of bovine under heat stress; Integration of allied sectors with farming can be an option to mitigate the impacts of climate change. There exists a number of ways agriculture smart through the allied sector, which includes use of community lands for fodder production during droughts and flood, improved fodder and feed storage methods, feed supplements, use of micro nutrients, preventive vaccination, improved shelters, etc. (Kumar et al, 2018). Increasing

the green fodder and concentrate feeds for lactating cattle and buffalo, the feed additives such as molasses urea products to cattle and buffalo and improved manure management may mitigate the options to mitigate the impacts of climate change (Sapkota et al, 2019). As livestock is the largest contributor to the GHG emission in the agricultural sectors, several mitigating measures have been advocated by the stakeholders to abate the emission of methane and nitrous oxide. The options such as improving the rumen fermentation efficiency, increasing green fodder dietary consumption (increased green fodder feed may reduce methane production by 5.7 %), increasing the concentrate feed (The increased concentrate feed would reduce methane production by 15-32 %), ensiled feed from forage reduces the methane production due to maximum digestibility; increasing the intake of feed additives (ionophores, antibiotics, halogenated compounds like condensed tannins, saponins or essential oils, propionate precursors (Fumarate and malate), culling of unproductive animals, increasing the use of IVRI rumen manipulation technique to reduce the emission of methane etc. likewise, manure management is a cause for the emission of GHG. In Maharashtra, several cattle camps have been organized by the government in the drought-prone areas to ensure the fodder and feed the demand of the livestock and the families dependent on the livestock (Udmale et al, 2014).

5.7 LET'S SUM UP

The impacts of climate change have been visible in the field of agriculture and caused a huge crop loss and income loss to the farmers as learnt in the chapter. Further, climate change in the agricultural and allied sectors has caused a severe socio-economic strain to the farmers as well as to the economy of the country. However, it is been observed that various adaptation measures promoted by research and extension system have reduced the adverse effects of climate change on crop and livestock production and productivity. It is also understandable from the chapter that numerous climate smart practices are followed by farmers have different success rate and adoption rates. On the whole, the adverse impacts of climate change can be minimized by the aggressive extension system by professionally identifying the anticipated and the existing vulnerability in the local areas (It will vary with the locations), screen the available technologies in the research organizations and universities, demonstrate them in the farmers field, which are suitable to the identified vulnerability and organize the farmers as collectives, provide real time weather and market related advisory services etc. would enable the farmers to prepare them to the emerging challenges of climate change.

5.8 CHECK YOUR PROGRESS

1. Describe the factors contributing to the climate change and role of agriculture in the global warming?
2. How do you measure the impacts of different climatic variations on agriculture and allied sectors?
3. How a location specific adaptive and mitigating measures can be taken up by the farmers?

4. Essential factors for creating a climate smart village and explain the roles of public private partnership?

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UNIT 6: INDIGENOUS TECHNICAL KNOWLEDGE (ITK)

Highlights of the Unit

- Objectives
- Introduction
- Features and importance of indigenous technical knowledge
- List of indigenous technical knowledge
- Relevance of indigenous technical knowledge to present context
- Indigenous technology and agricultural extension
- Documentation and validation of indigenous technical knowledge
- Let's sum up
- Check Your Progress
- Further readings/ references

6.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Meaning of indigenous technical knowledge
- Features and importance of indigenous technical knowledge
- Documentation on indigenous technical knowledge
- Relevance of indigenous technical knowledge to present context
- Documentation and validation of indigenous technical knowledge

6.1 INTRODUCTION

Indigenous Technical Knowledge is a traditional knowledge that has been developed by the people on their own while finding solution to the problems they are facing. Most of the ITKs are the result of the collective wisdom of the people for several generations through their experiments and observations from day to day life. These ITKs are developed also based on the cultural aspects of the community and it is transferred from one generation to the other generation. Some of the most evident and common examples of the Indigenous Technical Knowledge are Keeping neem leaves in the rice to avoid pest, smearing of the cow dung in front of the home, use of turmeric for healing of wounds.

In the words of Rehmat Khan Solanki "The only resource in which the poor are rich is their knowledge". These traditional knowledges may be in different forms like music, art, dance, crafts, symbols and the way it is transferred from one generation to the other. Generally, it is seen that these traditional medications are based on plant formulations, minerals and products of animal origin. The unique advantage is that India is one of the

world's 12 mega biodiversity centers having over 45,000 plant species and accounting for 8 per cent of global plant genetic resources and higher share of microorganisms (Bidwal, 1997). Its diversity is unmatched due to the presence of 16 different agro-climatic zones, 10 vegetative zones and 15 biotic provinces.

The country has 15000-18000 flowering plants 23,000 fungi, 2,500 algae, 1,600 lichens, 1,800 bryophytes and 30 million microorganisms. India also has equivalent to ¾ of its land, exclusive economic zone in the ocean harboring a large variety of flora and fauna, many of them with therapeutic properties (Kamboj, 2000). Also, the cost, inaccessibility, and other problems like side effects associated with the conventional animal health care system have led to the rediscovery of traditional wisdom (Ranganekar, 1996; Deshpande, 2000).

6.2 FEATURES AND IMPORTANCE OF INDIGENOUS TECHNICAL KNOWLEDGE

a. It is a local knowledge.
b. It is developed at the grass root level.
c. It is transmitted orally from one generation to next generation.
d. It is important component of the global knowledge.
e. It helps in solving problem.
f. These are the products that can be developed using the available local resources.
g. Sharing this knowledge can help in exchanging the cultural knowledge among different community.
h. It is important part of the lives of the poor people.

6.3 LIST OF INDIGENOUS TECHNICAL KNOWLEDGE

When farmers' identify ITKs with some logic whereas there will be scientific reason behind each of the practice.
Here let us find some of the ITKs with farmers' logic and probable scientific reason.

Table 1 List of Indigenous Technical Knowledge

Description of ITK	Farmers Logic	Probable Scientific Reason
I. Agriculture (Soil Management)		
1. Burning sugarcane trash in the field	Easy disposal of trash	Ensures sanitation and has soil sterilization
2. Coconut gardens are applied with 6 to 8 tons of tank silt/red earth per ha.	Improves nut size and yield	Tank silt/red earth improves soil properties and supply nutrients

II. Agriculture (Crop Management)		
1. Sunflower seed soaked in sour butter milk before sowing	Better germination	Acts as a growth retardant
II. Horticulture		
1. The cut ends of plant cuttings are pasted with cow dung ball	Better sprouting & rooting	Reduces desiccation and acts as growth promoter
2. Application of 200 ml butter milk to curry leaf plant every week	Improves aroma	Ensures availability of enzymes, vitamins and micro-nutrients

6.4 RELEVANCE OF INDIGENOUS TECHNICAL KNOWLEDGE TO PRESENT CONTEXT

In present day situation, Indigenous Technical knowledge are highly important as our soil and environment is highly polluted with the chemicals and having side effects. ITKs does not have negative effects, instead provide solution to the problems at affordable cost using locally available resources.

In agriculture, it is related to the crop production, plant protection, storage, animal husbandry and many more. All these agricultural and allied activities are carried out by the local people who don't have more contact with outside world. Major drawback of the traditional knowledge is that, most of them are not documented and hence it is difficult to validate such ITKs. Rural people and tribal people are the major sources of the ITKs.

Therapeutic value of the medicinal plants in India has been appreciated by the global development agencies and the people having these traditional knowledges are encouraged to take patent on these technologies.

Indigenous knowledge is relevant on three levels for the development process

a. It is, obviously, most important for the local community in which the bearers of such knowledge live and produce
b. Development agents need to recognize it, value it and appreciate it in their interaction with the local communities. Before using these ITKs, they need to understand and incorporate it.
c. Lastly, indigenous knowledge forms part of the global knowledge. In this context, it has a value and relevance in itself. Indigenous knowledge can be preserved, transferred, or adopted and adapted elsewhere.

6.5 INDIGENOUS TECHNOLOGY AND AGRICULTURAL EXTENSION

Indigenous technology is the knowledge available in the rural areas. The major sources of these knowledge are farmers, elderly people, heads of the village, NGOs, records, folklore etc. Extension agents' main role in rural area is to identify the problems in the

village, help farmers in finding and solving those problems. In context of the indigenous knowledge, they must interview the farmers, document the available knowledge and search for the records available and try to validate these ITKs and integrate them with the modern technologies.

6.6 DOCUMENTATION AND VALIDATION OF INDIGENOUS TECHNICAL KNOWLEDGE

6.6.1 Documentation of Indigenous Technical Knowledge: Indigenous technical knowledge will not be documented instead it will be transferred from one generation to the other generation. For validation of ITKs with the scientific reason, documentation is must.

Documenting of these ITKs can be done in different context like documenting variety of practices without scientific validation, prevalent practices present as well as comparing them with the traditional ones, documenting the practices evolved to mitigate the specific problems. Documentation can be done via taking audio recording, video recording, photos and notes.

6.6.2 Validation of Indigenous Technical Knowledge: Important steps involved in the validation of ITK are

a. **Prepare a list of all ITK practices:** ITK practices can be listed out and can be categorized.
b. Continuum can be prepared for rating the rationality of ITK

Sl. No.	Continuum	Weightage
1	Very rational	5
2	Rational	4
3	Undecided	3
4	Irrational	2
5	Very Irrational	1

c. Send the list of ITK along with weightage to the experts for their judgment on each indigenous technical knowledge.
d. Based on the scores given by all experts, calculate weighted mean score for each individual score.
e. Select practices above mean score
f. The ITKs which have got above mean score are considered as rational and hence validated.

6.7 LET'S SUM UP

Indigenous technical knowledge plays an essential role in sustainable grassroots innovations. Such grassroots innovation largely differs across different sectors with respect to the characteristics, sources, actors involved etc. The knowledge base needed for different grassroots innovations is different, which in turn decides the involvement of particular set of actors. In case of traditional societies, the local indigenous individual is

the major actor. In many cases, the indigenous communities are not well aware of the value of their indigenous knowledge which has been passing from generation after generation. Actors such as scientific institutions and NGOs could play crucial role in this regards for capacity building among the indigenous community and popularization of traditional methods and techniques. In today's context, there is an urgent need to evaluate and popularize indigenous innovation. Government schemes and Research and Development activities should reach indigenous innovators.

6.8 CHECK YOUR PROGRESS

1. Describe the meaning indigenous technical knowledge?
2. Explain relevance of indigenous technical knowledge in the present context?
3. List out some of the Indigenous technical knowledge?
4. Describe the methodology of validation of indigenous technical knowledge?
5. Explain some of the probable scientific reason for some of the indigenous technical knowledge?
6. Mention farmer's logic for three indigenous technical knowledge?

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BLOCK II: ROLE OF AGRI & ALLIED SECTOR FOR SUSTAINABLE AGRICULTURE DEVELOPMENT

UNIT 1: ROLE OF AGRI & ALLIED SECTOR FOR SUSTAINABLE AGRICULTURE DEVELOPMENT

Highlights of the Unit

- Objectives
- Introduction
- Role and status of Agri & allied sector in India
- Major challenges and issues Agri & allied sector in India
- Let's sum up
- Check Your Progress

1.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- The role and status Agri-allied sector for sustainable agriculture development
- Major challenges and issues Agri-allied sector in India

1.1 INTRODUCTION

Agriculture plays a vital role in India's economy. Nearly 54.6% of the population is engaged in agriculture and allied activities (census 2011) and it contributes 17.4% to the country's Gross Value Added for the year 2016-17 (at current prices).(Annual Report 2016-17, DAC & FW). The first phase of transformation of Indian agriculture (1950 – 70) was mainly driven by the need to achieve self-sufficiency in food grains as India was importing a large quantity of cereals, for meeting domestic shortages in 1950s and 1960s. The growth in food grain production during the first two decades, following the country's independence, was small. The grain output could touch close to 100 million tones only in 1974–75 from around 50 million tones reported during 1950 – 51.

Post-independence era, the area under irrigation was low and there were frequent droughts and the prime objective at that time was to make adequate food supplies available to the increasing population and ensuring provision of raw materials for the expansion of industrial sector. This was to be achieved by way of - imports, reorganization of the agricultural sector and a series of development measures encompassing expansion of irrigation and extensive as well as intensive farming. These initiatives were given further boost by strengthening agricultural administration and kicking off special area programs.

The advent of new high yielding varieties brought Green Revolution in late 1960s, which in combination with expansion in area under cultivation and usage of chemical fertilizers increased the output of cereals, mainly – wheat and rice, followed by other coarse cereals such as maize to a certain extent chiefly in Punjab, Haryana and western Uttar Pradesh.

The early phase of green revolution was largely associated with the spread of new technology to better endow and irrigated regions of northern India, therefore, special efforts were then made to spread new technology into those regions, which had remained outside the fold of technological revolution. Consequently, special programmes were launched during late 1970s and mid-1980s.

The second phase of transformation (1970 – 1990) witnessed a play of a combination of expansion of the Green Revolution into new crops and areas and introduction of the 'White Revolution' or also known as Operation Flood, which laid the foundations for consolidation of gains made in first phase and led to enormous growth of milk production in the country during 1980 and 1990s.

In the most recent phase of transformation, witnessed since early 1990s saw the launch of economic reforms and liberalization of the economy. There was a significant shift in the drivers of transformation which focused from the supply side factors to the demand side factors. Though there was a sizeable growth in gross irrigated area the huge increase in the usage of fertilizers witnessed in earlier two phases also decelerated. Although there was an increase in the road network and electricity generation and investment in the agricultural and allied sectors also expanded. But the supplies of all main commodities like cereals, oilseeds and sugarcane did not show much increase. The only exceptions were fruits and vegetables and cotton, the supplies of which increased significantly during this period. The production of horticulture crops that include mainly vegetables and fruits stood at an all-time high 283.47 million tones (MT) in 2014-15, compared with the grain volume of 257.07 MT.

The noteworthy aspect is that aquaculture and catch fishery is amongst the fastest growing industries in India. Fisheries at present supports livelihood of almost 1.5 million people. During 1990 - 2010, the Indian fish capture harvest doubled, while aquaculture harvest tripled.

1.2 ROLES AND STATUS OF AGRI-ALLIED SECTOR IN INDIA

The contribution of Agri-allied sectors viz., livestock (including dairy, sheep, goat, poultry and piggery), fisheries (marine, inland and aqua farming), horticulture (including fruits, vegetables, flowers, spices, aromatic and medicinal plants) and sericulture sector has been significant and growing over the years. Globally, India accounts for the highest milk production, second highest fish production and second highest production of fruits and vegetables.

1.2.1 Livestock sector: Livestock sector is an important sub-sector of agriculture which provides nutrient-rich food products, draught power, organic manure and domestic fuel, hides and skin and is a regular source of cash income for rural households. Over the last two decades, livestock sector has grown significantly. According to estimates of the Central Statistics Office (CSO), the value of output of livestock sector at current prices during 2015-16 was about 28.6 % of the value of output from agricultural and allied sector. (28 % at constant prices) (Annual Report 2016-17, DAC & FW).

Currently, India accounts for 18.5 % of world **milk production.** In 2016-17, with annual growth rate of 6.37 %, milk production reached **165.4 million tons.** The per capita milk availability is **355 gm per day** per person, considerably higher than recommended by ICMR i.e. 280 gm per day per person. (Annual Report, DAHD&F, 2017-18)

Uttar Pradesh, Rajasthan and Madhya Pradesh are the highest milk producing states contributing 37.8 % of total milk production.

The Indian dairy cooperative network consists of **1, 77, 314** primary milk cooperative societies at village level covering **16,282** producer members and procures 42.8 million kg milk per day. (Annual Report, NDDB, 2016-17). Approximately, 34% of the milk is sold in the unorganized market while 46% is consumed locally. This is in contrast to most of the developed nations where almost 90% of the surplus milk passes through the organized sector. As per the Department of Animal Husbandry, Dairying and Fisheries, organized milk handling is expected to grow from 20% at present to 50% by 2022-23.Annual Report, DAHD&F, and 2017-18)

Presently, the co-operatives and private dairies have access to only 20 % of the milk produced. However, it is estimated that, by 2020, private corporate dairies will overtake cooperatives in handling of milk volumes, which is projected to reach 28.93 million tons, ahead of the 23.67 million tons of cooperatives. (National action plan for dairy development: Vision 2022).

The total **meat production** in the year 2016-17 reached 7.4 million tones among which the major contribution is from poultry 47.05 % followed by buffalo 19.80 %, goat 14.25 %, and sheep 7.68 %, pig 6.50 and cattle 4.72 %. (Annual Report, DAHD&F, 2017-18). The per capita availability of meat is around 5 kg. Per person per year, which is nearly half the recommended level i.e. 11 kg per person per year by ICMR.

India ranks third in **egg production** in the world after China and the USA and is the fourth-largest producer of chicken in the world after China, Brazil and the USA. In 2016-17, egg production reached 88.14 billion with annual growth rate of 6.3 %. The per capita availability of eggs is around 69 eggs per person per year, which is far below the recommended level i.e. 180 eggs per person per year by ICMR.

Tamil Nadu, Andhra Pradesh and Telangana ranked the largest egg producing states, contributing more than half (50.3) of the total egg production.

Uttar Pradesh, Maharashtra and West Bengal are the highest meat producing states contributing nearly forty percent of total meat production.

The total value of poultry sector is about Rs.80, 000 crore (2015-16) broadly divided into two sub-sectors – a highly organized commercial sector with about 80 % of the total market share and the unorganized with about 20 % of the total market share. (Annual Report, DAHD&F, 2017-18).

1.2.2 Fisheries and Aquaculture sector: The fisheries and aquaculture sector is recognized as the sunshine sector in Indian agriculture providing nutritional security to the food basket, contributing to agricultural exports and engaging about 14 million people in different activities. There have been continuous and sustained increments in fish production in India since independence. Constituting about 6.3% of the global fish production, India stand 2nd in total fish production as well as freshwater fish production. The total fish production in 2016-17 was 11.4 million metric tonnes (3.6 million metric tonnes from marine fisheries and 7.8 million metric tonnes from inland fisheries). The per capita availability of fish is 9 kg per person per year, which is quite low as compared to other developing nations. The sector contributes to 1.1 % of the national GDP and 5.15% of the agricultural GDP. (Annual Report, DAHD&F, 2017-18).

Andhra Pradesh, West Bengal and Tamil Nadu are the top three fish producing states.

In order to utilize the large untapped potential in fisheries and aquaculture in the country, the Government of India started **Blue Revolution** creating an enabling environment for integrated development of the full potential of fisheries in the country, along with substantial improvement in the income status of fishers and fish farmers keeping in view sustainability, bio-security and environmental concerns.

1.2.3 Horticulture sector: India has maintained leadership in the production of many commodities like mango, banana, acid lime, coconut, arecanut, cashew, ginger, turmeric and black pepper. Presently, it is the second largest producer of fruits and vegetables in the world. India is next only to China in area and production of vegetables and occupies the prime position in the production of cauliflower, second in onions and third in cabbage in the world. India has also made noticeable advancement in the production of flowers. Further, it is the largest producer, consumer and exporter of spices. India is home to a wide variety of spices like black pepper, cardamom (small and large), ginger, garlic, turmeric, chili and a large variety of tree and seed spices. The major spice producing States are Andhra Pradesh, Tamil Nadu, Odisha and Madhya Pradesh. The North Eastern region and Andaman and Nicobar Islands also have potential areas for spices, particularly cultivated organically.

Andhra Pradesh, Maharashtra and Uttar Pradesh are the leading states in fruit production for 2016-17.

The percentage share of horticulture output in Agriculture is 30%. Over the last decade, the area under horticulture grew by about 3% per annum and annual production increased by 5.4%. During 2016-17, the production of horticulture crops was about 295.2 million tonnes from an area of 24.9 million hectares. Among the horticulture crops, vegetable crops account nearly 60 %, followed by fruits (31.5 %), Plantation (5.7 %), Spices (2.4 %) and flowers and aromatic plants. During 2016-17, the area under vegetables in India is estimated at 10.3 million hectares with a production of 175 million tonnes. India produces nearly 11 % of all the world's vegetables and 15 % of all fruits. Uttar Pradesh, West Bengal

and Madhya Pradesh are the leading states in vegetable production for the year 2016-17 (Horticulture Statistics at a Glance, 2017).

1.2.4 Sericulture sector: Sericulture is a major sub-sector comprising the textiles sector. Sericulture emerged as an important economic activity, becoming popular in several parts of the country, because of its short gestation period and quick recycling of resources. It suits all types of farmers and exceptionally marginal and small land holders as it offers rich opportunities for enhancement of income and creates family employment round the year.

India is the second largest producer of silk in the world and has the distinction of being the only country producing all five kinds of silk namely Mulberry, Eri, Muga, Tropical Tasar and Temperate Tasar. Karnataka, Andhra Pradesh and Assam were the top three raw silk producing states in 2016-17. In 2016-17 total raw silk production reached 30,348 metric tonnes with an annual growth of 6.4%. However, the demand for silk is more than the production. In 2016-17 a total of 3795 metric tonnes of raw silk worth Rs.1092.26 crore was imported mainly from China, to supplement the domestic production for meeting the increasing demand. (CSO, Annual Report 2016-17). India holds the monopoly in producing Muga silk. It is the only cash crop in the agriculture sector that gives returns within 30 days.

1.3 MAJOR CHALLENGES AND ISSUES OF AGRI-ALLIED SECTOR

Agri-allied sector facing several challenges related to low productivity, inadequate infrastructure for processing and value addition, designated human resources, poor extension services and also policy issues.

1.3.1 Livestock sector: The Agri-Allied sectors face certain challenges and issues which are listed here.

1. Low productivity: there is need to enhance the levels through genetic improvement along with practices such as; improving feed utilization efficiency, adopting better reproductive strategies and improving health coverage based on newer generation biotechnological vaccines and drugs.
2. Shortage of feed and fodder
3. Unorganized: Livestock sector particularly small ruminants; sheep, goat, piggery are highly unorganized.
4. Inadequate infrastructure for marketing, processing and value addition
5. Marketing of livestock and livestock products remains largely unorganized, traditional, and fragmented, with a few exceptions.
6. Livestock and environment: Climate change aggravates heat stress in dairy animals, adversely affecting their productive and reproductive performance. The estimated annual loss at present due to heat stress at the all-India level is 1.8 million tones. Livestock are itself a large source of methane emission contributing about 18% of total enteric methane budget.

7. Knowledge gap. As per National Sample Survey Organization (NSSO) survey conducted in 2003, only 5.1 % of the farmer households in India were able to access any information on animal husbandry as against 40.4 % on crop farming. (Chander M. et al, 2010). 60 % of farmers had not accessed any source of information on modern technology to assist in their farming practices.
8. Poor extension services: There is increased demand for various services like animal breeding, health care, feed and fodder production, marketing, livestock extension etc. which are provided by multifarious agencies in India. Among all the services, livestock extension services play an important role in empowering farmers with appropriate technological knowledge and skills through various extension education and training programs.

1.3.2 Fisheries and Aquaculture sector: Challenges for fisheries development in India include the following:

1. Inland fishery not treated at par with agriculture in the context of taxes, electricity tariff etc. and therefore fishery sector remained largely un-organized and traditional in most parts of the country with little proliferation of technological improvement
2. Absence of inland fishery policy at national level
3. Non-coverage of fish farming under insurance
4. Lack of a reliable database relating to aquatic and fisheries resources
5. Non-availability of suitable fish yield models for multi-species fisheries for open inland waters and marine resources
6. Weak multi-disciplinary approach in fisheries and aquaculture
7. Inadequate attention to environmental, economic, social and gender issues in fisheries and aquaculture
8. Inadequate human resource development and specialized manpower in different disciplines
9. Weak linkages between research and development machinery
10. Weak and unorganized marketing
11. Poor extension services to the fisher communities for promotion of fish seed and feed production, fish farming and fish based enterprises
12. Poor technology transfer and anthropogenic interventions, resulting in loss of biodiversity
13. Decline in fish catch, depletion of natural resources due to over-exploitation of coastal fisheries
14. Pollution of water bodies with industrial and domestic effluents
15. Clandestine introduction and spread of exotic fish species
16. Unscientific management of fisheries and aquaculture activities
17. Contamination of indigenous fish germplasm resources
18. Poor yield optimization, problems in harvest and post-harvest operations, landing and berthing facilities for fishing vessels and issues in welfare of fishermen.
19. Lack of value addition for enhancing profit margin
20. Lack of location specific improved technology

21. Lack of timely availability of inputs nearby
    (Mishra N. 2012,)
22. Lack of effective extension services

It can be seen that extension services provided by the Government agencies are inadequate (Kumaran et al., 2004 and 2007; Kumar, 1996). The focus of aquaculture extension needs to shift from mere technology dissemination to areas like value addition, quality control, market demand and consumer demand. The most limiting factor with department of fishery is inadequate staff support complemented with inappropriate extension infrastructure, unequal distribution of physical and financial resources during budget allocation and lack of technical content because of the feeble linkages presently existing between the state department of fisheries and research institutions (Kumar and Ananthan, 2009; Kumar, 1996). Presently, there is no platform or institutional initiative to assure periodic discussion between researchers and farmer extension agencies as in agriculture (Krishna, 2000). Inputs and service provision rests mostly with private companies or individuals (Kumaran et al., 2012). The Coastal Aquaculture Authority Act (2006) specifies that extension services shall be effectively intensified in such a way that the actors involved viz., extension personnel, fish farmers and other related personnel can improve their technical expertise and skills, thus facilitating sustainable aquaculture. Absence of formalized extension policies in developing countries is the main challenge in extension as most of the developing countries prefer policies that are provisional or ad hoc (Van den Ban and Hawkins, 1996). Extension efforts aimed towards fish farmers for transfer of technology is found to be limited only to the area where Fish Farmers Development Agency (FFDA) is functioning (Dehadrai, 1986).

1.3.3 Horticulture sector: Challenges for horticulture development in India include the following:

1. Lack of quality inputs
2. Lack of market support
3. Paucity of post-harvest management, packing and storage, specialized transport and storage arrangements to maintain the chain from farm to fork
4. Increasing cost of production; most growers do not get reasonable returns for their produce
5. Distress sales
6. Inadequate infrastructure like transportation, cold storage, warehouses etc.
7. Price fluctuation
8. Lack of market intelligence
9. Lack of knowledge of post-harvest handling
10. Wastage and spoilage loss
11. Lack of mechanization due to small land holding
12. Weak extension services

Horticulture extension has been an integral part of agricultural extension services. During the last few years there has been diversification of agriculture towards high value

commodities such as fruits and vegetables. Considering the evolving challenges, producers currently need a wider range of support - organizational, marketing, technological, financial and entrepreneurial. Deterioration of quality of agricultural extension services in general and horticulture extension services in particular is observed, with experts and extension workers finding themselves lacking in capacity to recommend technology solutions to the producers. Therefore there is need to strengthen the technology support system. Most of the extension personnel perform multiple roles. Their visits to the field are irregular as the service is pre-occupied with the implementation of government schemes linked to subsidies and subsidized inputs.

In the State Directorates of Horticulture, administrative functions are generally assumed by the extension functionaries positioned at higher levels along the hierarchy line and extension work is left to the lower level / lowest functionaries. Most of these functionaries have academic qualifications of agriculture / horticulture but do not have direct exposure to farming; as a result they lack confidence in addressing field level problems faced by farmers.

(Report of Planning Commission Working Group on Horticulture and Plantation Crops for XIIth Plan-2011)

ICAR Institutions and SAUs basically concentrate on research and education; extension service is very limited, confined to organization of exhibitions, training programs and demonstrations etc.

Extension Services by Input Suppliers - A number of private seed companies, pesticide and insecticide companies provide extension services and transfer production and post-harvest management technologies to producer farmers. However, due to lack of technical knowledge of products this may result in indiscriminate use of farm chemicals.

Extension Services by Contract Buyers - Buyers who enter into contract production program of horticulture crops for exports, processing or domestic marketing do supply seed and planting materials, other farm inputs and relevant technologies. They may also provide cold chain and packaging solutions for long distance transport of produce.

This group is a very effective in transfer of technology in respect of certain specific horticulture crops.

1.3.4 Sericulture sector

The Indian sericulture industry, is currently facing several problems which have restricted full utilization of its potential.

1. Indian silk yarn is of poor quality, which not only affects our competitiveness in the world market, but has also resulted in a preference for imported yarn in the domestic market. There is lack of: Sufficient thrust on the adoption of improved technologies; Strict disease control measures; Quality leaf due to insufficient inputs to mulberry garden; Grading system for cocoons and Quality-based pricing system as well as use of young age silkworms
2. Decline in area under silk food plants: This can be addressed by initiating area-specific research to improve soil fertility which will ultimately enhance soil productivity,

increase mulberry and non-mulberry host plant leaf and silkworm cocoon production as well as arrest decline in area under silk food plants.

3. Insufficient production of bivoltine silk: Bivoltine yarn is sturdier and is used by the power loom industry. But only 5% of the silk produced in India is bivoltine because its production requires more attention and resources. It also yields just two crops in a year, as against the yield of four to six crops by multi-voltine silk. Even the farmers do not have any incentive to switch to bivoltine silk yarn production because the difference between the selling price of bivoltine and multivoltine silk is not much. (CSO, Annual Report 2016-17).
4. The other factors responsible for it are;
   a) Insufficient adoption and proliferation of technology packages developed through research and development efforts
   b) Fragmented and ad hoc approach
   c) Non-involvement of private partners in a big way in seed production
   d) Non-penetration of the schemes
   e) Improper forward and backward linkages
   f) Dumping of cheap Chinese raw silk and fabric
   g) Inadequate extension services

In Sericulture sector, only few states like Karnataka, Himachal Pradesh are doing effective extension activities. Apart from the State Department, Central Silk Board, a strong Capacity Building & Training organization, has covered a total of 16,690 industry stake-holders and CSB's in house participants covering all the sub-sectors (mulberry, tasar, eri & muga) and activities on the silk value-chain. In addition, a total of 2275 college students and school children were exposed to sericulture. With a view to facilitate farmer–to-farmer contact for information sharing and technology demonstration 11 Sericulture Resource Centers (SRCs) were established in different Seri-Clusters including North-eastern region. (CSO, Annual Report 2016-17).

1.4 LET'S SUM UP

Agriculture and allied sector enjoy the role of the largest employment provider, it is to note that from a food grain deficient nation prior to the Green Revolution, at present, India is one of the largest producers of food grains in the world. The Green Revolution was followed by White Revolution, India tops in the list of major milk producing countries. It is estimated that, by the year 2030, production of all livestock commodity needs to be double from its exiting level to fulfill the increasing demand of the products. The success rate in horticulture sector is especially note-worthy. After China, we are the largest producer and exporter of flowers, fruits and vegetables. Moreover, the Blue revolution to boost fish production mainly from inland fishery is also under progress. However, fragmentation of land holdings, deficient monsoon rainfall and natural calamities, the loss in perishables goods are continues to be very high due to inadequate infrastructure. The loss in fruits and vegetables alone comes between 6 and 18 per cent

per year. To enhance productivity and production of Agri-allied sector and thereby livelihoods of the under privileged families, State Department of Agri-allied sector needs to focus on extension activities. Presently, nearly all State Department of Animal husbandry are focusing on delivery of clinical and reproduction oriented services to livestock farmers. In fact these officers have a very broad mandate of livestock sector development of which livestock extension is an inevitable part but it remains weak and neglected. Majority of the states don't have separate department of horticulture and sericulture. Though the fishery sector have separate department in most of the states, however extension component are very weak and neglected. Moreover public funding on extension activities needs to be increase in all Agri-allied sector. The inter-disciplinary action-oriented research should target communities holding small land holding, small livestock flocks and farm ponds. It is recommended that the research should start by ensuring a shared understanding between research-for-development teams and the underprivileged communities of the preferences of the communities for specific types of enterprise, their perceptions (particularly of the women) about the roles and functions for livelihood strategies needs to be worked out.

1.5 CHECK YOUR PROGRESS

1. State the status of agri-allied sector in India?
2. Define the role of agri-allied sector in India?
3. What are major challenges of agri-allied sector in India?

1.6 FURTHER READINGS/ REFERENCES

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UNIT 2: SUSTAINABLE LIVESTOCK PRODUCTION
A. NUTRIENT MANAGEMENT FOR SUSTAINABLE LIVESTOCK PRODUCTION

Highlights of the Unit

- Objectives
- Introduction
- Importance of nutrition management
- Strategies to reduce the nutrient deficit and improve the nutrient availability
- Let's sum up
- Check Your Progress
- Further readings/references

2. A.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Role of nutrition in livestock management
- Nutrition management for different farmed livestock

2. A.1 INTRODUCTION

Dairy cattle should be fed to meet but not to exceed their nutrient requirements. Feeding diets that are deficient in any nutrient will decrease production of milk and milk components; however, feeding excessive amounts of a nutrient will decrease the efficiency of nutrient utilization, which results in increased nutrient excretion into the environment, increased cost of milk production, decreased profits for dairy producers, and increased costs for the consumers of dairy products. Hence, it is very essential to understand the nutrient requirements of animal for different purposes so that there would not be any excess or under feeding to the animals.

2. A.2 IMPORTANCE OF NUTRITION MANAGEMENT

Nutrition is one of the most important factors influencing performance, health and welfare of animals. Feed is the largest input for dairy production accounting for 65-70% of total cost of production and thus any saving in feed and fodder cost would directly contribute to increase in profitability. The adequate un-interrupted availability of feeds and fodder is a pre-requisite for improving the productivity of animals and to make livestock production efficient. But the country is facing chronic shortage of feed and fodder resources for livestock growth. In India only 4.4 per cent land is under fodder and

forage crops cultivation as against the recommendations of 8% of total cultivable land and it remained almost static since last few decades. Currently, the country faces a net deficit of 62.8% green fodder, 23.5% dry crop residues and 65% compounded feeds (ICAR, 2013). The future predictions by ICAR revealed that by 2025 the feed and fodder availability will remain more or less constant i.e., there will be a deficit of 61.9% green fodder, 24.0% dry fodder, 25.38% crude protein and 23.14% TDN. Thus, there is a need to bridge the nutrient deficit to improve the livestock productivity according to its genetic potential.

2. A.3 STRATEGIES TO REDUCE THE NUTRIENT DEFICIT AND IMPROVE THE NUTRIENT AVAILABILITY

2.A.3.1 Utilization of available feed resources: In today's scenario, on one side the grazing lands are shrinking and on the other side more and more cultivable land is diverted for food crop production to meet the food demands of growing human population, thereby reducing the land for fodder production. In such a situation, enormous quantities of crop residues that are available in the ratio of 1-3 times the yield of grains/seeds from cereals, legumes, millets and other crops after harvesting could form the major proportion of feeds of livestock. Crop residues contribute to extent of 68% of total dry matter that is being consumed by the dairy animals. About 500 MT of crop residue is generated every year (MNRE 2009). Cereals generate highest (352 Mt) residue followed by fibres (66 Mt), oilseed (29 Mt), pulses (13 Mt) and sugarcane (12 Mt). (IARI 2012). Presently most of these straws are thrown out as waste, used as manure or burnt to clean field or as fuel in the villages. Apart from paddy straw and wheat straw, many other crop residues (conventional/unconventional) and agro-industrial by-products like maize cobs, cotton straw, sunflower heads, sunflower straw, groundnut hulls, cottonseed hulls, sugarcane bagasse, sugarcane tops, castor straw, etc. can be utilized as roughage component for various classes of livestock.

Qualitatively, the crop residues are less palatable and digestible, generally low in protein and minerals, rich in fiber and having low bulk density. This result in reduced intake and lowered digestibility, in turn animal cannot meet even the maintenance requirements. Efforts should be made to enhance the utilization of these crop residues by employing suitable processing techniques. Any improvement in the nutritional quality of crop residues will enhance nutrient supply to the livestock. One of the promising method of utilizing these bulky crop residues, as ruminant feed is to blend them along with concentrates in well-balanced complete feeds.

2.A.3.2 Concept of Complete feed: Complete feed is a mixture of various processed feedstuffs (roughages and concentrates) containing all dietary nutrients, except water. It is presented in the form, which precludes selection and is offered as the sole source of feed. The main concept of the complete diet system is that all feed ingredients inclusive of roughages and concentrates are processed and mixed into a uniform blend. This blend

is made available to the animal as a sole source and free choice, thus ensuring the supply of diet of the same composition every time.

Advantages of complete feed:

1. Better feed consumption
2. Avoids refusal of unpalatable portion of feedstuffs
3. Increase scope for using cheap and bulky by-products available locally
4. Feed intake by animals could be monitored closely
5. Enables to control the ratio of concentrate to roughage and reduces feeding cost
6. The eating and rumination time is reduced, increases the resting time in animals
7. Maintain normal acetic to propionic acid with less fluctuation in the release of ammonia in rumen
8. The non-protein nitrogen is more efficiently utilized.

Table 1. Feeding schedule of cows

Milk Yield in Kg	Requirements			Source of feed	
	Dry Matter (DM) in Kg	Digestible Crude Protein (DCP) in Kg	Total Digestible Nutrient (TDN) in Kg	Concen -trates (Kg)	Fodder (Kg)
Up to 10	12.0	0.8	6.6	2.0	10.0
10.1 to 13.0	13.0	0.9	7.7	3.0	10.0
13.1 to 16.0	14.5	1.1	8.8	4.0	10.5

2. A.3.3 Processing of complete diets: The complete feeds formulated with the crop residues in mash form are bulky. The bulkiness of the complete diet depends on the proportion of roughage and type of roughage. Thus the transportation of the complete diet in mash form proves costly. Thus the crop residue based complete diets could be further processed by pelleting/ expander extrusion or densification into blocks.

Advantages of feeding processed complete diet:

1. Growth rates of calves increases by 30-40%
2. Milk yield increases by 10-15%
3. At times increase in milk fat %
4. Persistency in peak milk yield for longer time
5. Attain early maturity & early age at 1st calving
6. Animals get conceived within 2-3 months after calving – thus improving overall reproductive efficiency of animals
7. Bulk density increases 3-4 times, so easy to handle store and transport
8. Labor expenditure reduced by 30-40%
9. Reduce environmental pollution by 10-15%

2. A.3.4 Strategic supplementation: More often the diets of animals under the field conditions are deficient in energy and protein. Identifying the limiting nutrient and supplementing energy in the form of cereal grains (maize, sorghum, finger millet) or protein in the form of oil cakes can improve the milk production by half to one liter per animal. This strategy has been successfully tested under farmer's field conditions with different roughage sources – paddy, finger millet and sorghum Stover based diets in Maharashtra, Karnataka and Andhra Pradesh. This approach can be easily adapted to different feeding situations in the different parts of country using locally available energy and protein supplements.

2. A.3.5 Precision mineral nutrition/Area Specific Mineral Mixture (ASMM): Minerals play critical role in ruminant's nutrition. A dairy animal producing 15 kg of milk per day requires about 60g- 80g of calcium per day, 30 g of phosphorus per day similarly other mineral requirement are also at higher level. However, indiscriminate feeding of minerals will lead to adverse interaction in the metabolic pathways resulting in decreased production in spite of sufficient supplementation hence, it is very vital to quantify the amount of minerals that is available in feeds and fodder before formulating a ration, as mineral profile of soil varies from region to region and depending on the deficiency of minerals supplementation can be done.

The mineral deficiencies are specific to different regions due to difference in soil composition, intensity of cropping, cultivation practices, type of feeds and fodders available, precipitation and soil erosion pattern, etc. The common mineral mixtures available in the market do not consider the region specific mineral deficiencies and excess. Thus there is a need to introduce the Area Specific Mineral Mixture (ASMM) into animal feeding practice so as to minimize the cost of mineral mixture drastically, reduce mineral interactions and environmental pollution result in increased per capita milk production, reproductive efficiency and reduce the incidence of health disorders. The ASMM contains only the required minerals in required quantities for the animals in that region.

Supplementation of area-specific minerals that are most deficient in that area avoids antagonistic effects of excess levels of other minerals, thereby improving the bioavailability of minerals and could be a more practical and cost effective approach. The ASMM Technology does not have any adverse or side effects either on animals or on humans using animal products and it minimizes environmental pollution.

2. A.3.6 Bypass nutrients: Although the concept of bypass nutrients- protein and fats started in western countries and targeted for high producing animals, surprisingly in Indian crossbreds and buffaloes with moderate to low production potential, the concept of bypass proteins and fats was found to have a positive production response. This in turn resulted in production of bypass protein feeds by a large number of the feed mills in the co-operative and private sector and the steady increase in the quantity of the bypass feed produced over the years. Of late bypass amino acids, especially lysine and

methionine are being used in milch animals, and the production responses have been quite positive. Few of the private firms have started marketing these products and with the increasing productivity and the need for better efficiency it is likely that "targeted nutrition technologies" – that is supplementing the required nutrients precisely will catch up in a large way.

Table 2.Nutrient requirement of growing cattle

Animal	Body Weight in Kg	Requirements		
		Dry Matter (DM) in Kg	Digestible Crude Protein (DCP) in Kg	Total Digestible Nutrient (TDN) in Kg
Calves 6-12 months	150	3.7	0.3	2.6
Young stock 1-2 years	300	7.5	0.4	4.0
Young stock over 2 years	400	10.0	0.4	4.3
Down calvers	450	11.2	0.4	4.5
Dry animals	450	11.2	0.4	3.4
Bulls	550	13.7	0.5	4.0

2.A.3.7 Ration balancing: Ration balancing is the process to balance the level of various nutrients for an animal, from the available feed resources, to meet its nutrient requirements for maintenance, production and optimal growth. The general feeding practices are based on the agricultural residues, by products and other locally available resources. This type of feeding is generally inadequate and more often there is imbalanced nutrition leading to inefficient production and wastage of resources. User-friendly software for ration balancing is available and a dedicated local resource persons (LRPs.) should be trained to effectively use the software in the local language. The software involves assessing nutrient status of animals, chemical composition of locally available feed resources, nutrient requirement of animals and formulating least cost ration using locally available resources. The concept of ration balancing has been tested widely by the National Dairy Development Board in Western India, and the results have been very positive in terms of improved productivity, resource utilization, sustainability, and feed costs. There is a need for wider adoption of this approach, which can have a large positive impact on the dairy production and feed resources' utilization.

2.A.3.8 Improving availability of green fodders: Green fodders being one of the best economically viable nutritive fodder sources, enhancing the production of green fodder will certainly help in increasing the production and profitability of dairy sector. As only 4.04 percent cultivable land is under fodder and forage cultivation, there is a need to increase the fodder production within the limited area by developing improved varieties which can yield higher quantity in shorter duration. The efficiency of utilization the

available land and water resources have to be maximized by encouraging fodder production in mixed farming system, making better use of waste lands denuded, degraded, marginal and sub marginal lands for the development of pastures and agro forestry systems. Improving forage quality and round the year forage production in milk shed areas along with taking up grass and tree based systems like lay and alley farming for dry land areas and drought prone areas, encouraging fodder production in tank beds in summer.

Table 3.Estimated daily water intake of various groups of cattle

Body Weight in Kg	Water requirements in liters at different temperatures	
	20^0C	30^0C
Heifers		
50	3.6	5.3
100	11.0	16.3
200	20.0	26.5
300	27.3	37.0
400	35.2	46.2
Lactating cow		
400	26.5	27.0
500	31.0	32.0

2.A.3.9 Preservation of fodder: Preservation of fodder is necessary to reduce the disadvantages of seasonal feed deficits and counter draught condition which is common phenomena in Indian continent. Preservation may be done either as hay, silage, haylage, wastlage and dehydration. Preservation of fodder depending on prevailing regional condition will certainly help in overcoming scarcity due to regional variations in crop productions due to different agro climatic conditions. Silage is highly palatable and furnishes high quality forage in any desired season of the year at a low expense. As there is an acute shortage of green fodder during the summer months, silage preserves 85 per cent or more of the feed value of the crop can meet this deficiency during that part of the year. The ensiling process kills practically all weeds that are present in the field because of their harvest before seed formation and thereby stopping dissemination of their seeds.

a. Hay making: Hay making is the process of turning green, perishable forage into a product that can be safely stored and easily transported without danger of spoilage, while keeping nutrient loss to a minimum. This involves reducing its moisture content by drying the forage in the sun. The process of drying the green crop without significant change in aroma, flavor and nutritive quality of forage is called "curing". This involves reducing the moisture content of green forages, so that they can be stored without spoilage or further nutrient loss.

b. Silage making: Silage is any grass, such as corn or millet crop, that is chopped into small pieces, added inoculant agents and compacted in a silo, bunker, bags, or made into bales. Silos and bunkers are for large captive consumption, whereas bags and bales are smaller chunks of silage which can be easily transported to various farms. Among the all types of silage Bale Silage is becoming popular**.** Baling is the process of wrapping compacted and inoculated grass in polypropylene sheets. The sheets should provide an airtight environment for the silage so that the fermentation of the grass occurs without oxygen. The high quality of polypropylene sheets supports airtight sealing, puncture resistance, and withstands the stretching that occurs during storage and transportation.

Table 4 Nutrient values of silage

Particulars	Unit	Avg.	Min.	Max.
Dry Matter (DM)	% as fed	32.5	30.0	34.9
Crude Protein	% DM	7.0	4.9	10.2
Crude Fiber	% DM	20.3	15.8	26.3
NDF	% DM	44.4	38.2	57.2
Gross Energy	Megajoules/kg DM	18.8	16.9	18.8

a. Haylage: Haylage is semi-dried fodder crop, usually cut like hay, but only allowed to semi-wilt and not dry completely. It is usually cut after grasses for silage, but several weeks earlier than grass cut for hay. Haylage is often baled between twenty four and forty eight hours of being cut or when the levels of moisture are only reduced to around 45-50 percent. The bales are then compressed and wrapped in multiple layers of plastic, often known as 'double wrapping'. This eliminates oxygen reaching it and creates the anaerobic conditions needed for desirable fermentation of the haylage to occur. This 'desirable fermentation' is necessary to allow bacterial species such as lactobacilli which are naturally present in the crop to utilize water soluble carbohydrates to survive and produce lactic acid. The production of lactic acid is important as this is what causes the pH to drop to a level between 4.8 and 5.8, which inhibits the growth of undesirable organisms.

b. Wastelage: A material obtained after ensiling of waste material (animal organ waste) in a suitable combination with forages and additives, under anaerobic condition through fermentation by lactic acid producing bacteria.

2.A.3.10 hydroponically grown fodder: Hydroponics is supplementary and sustainable way to produce quality green fodder. It is a scientific way of growing plants/crops in water without any soil in controlled environment. The advantage of hydroponic fodder production is that it requires just 480 Sq. Ft. area to produce 1000 kg every day against 5-30 acres land under conventional system, along with saving of water up to 95%. It has

other advantages such as; round the year fodder production, saving on labor, energy and time. Hydroponic fodder can be produced using greenhouse or poly house systems which is capital expensive initially and can produce fodder commercially or can be produced in a simpler way using cheap recyclable materials like old wooden boxes, PET bottles, bamboo, etc. The disadvantage of hydroponically grown fodder is its low dry matter content. There are different models of hydrophonic unit based on cost of establishment and durability such as;

a. Economy model: This type of unit is made from bamboos, shed net, plastic trays, foggers and timer assembly. The dimensions are 50 x 15 x 7 feet. The cost of construction is approximately Rs. 1.20 lakh. Which includes cost of bamboo Rs. 25000, plastic trays Rs. 60000 (300 trays), irrigation system Rs. 25000, shade net Rs. 4000, labour charges Rs. 6000. The life of this unit is approximately 3years. It has the capacity to accommodate 300 trays which can produce600 kg green fodder per day.

b. Steel structure: The durability of this model is approximately 10 years. The only difference is in its construction, instead of bamboo GI pipes are used. The cost this unit works out to Rs. 2 lakh. The production capacity is 600kg per day.

2.A.3.11 Azolla feeding in cattle: Azolla is a free floating, rapidly growing aquatic fern on water surface containing good quantity of protein, minerals and vitamins. Under ideal conditions it grows exponentially, doubling its biomass in every three days. There are at least eight species of Azolla worldwide. The common species of Azolla in India is Azollapinnata. It produces more than 4 to 5 times of protein of excellent quality in comparison to Lucerne and hybrid Napier. Besides this, the bio- mass production is almost 4 to 10 times when compared with hybrid Napier and Lucerne, respectively. These two parameters are very important to enhance economic livestock production to establish that Azolla is reckoned as "The Super Plant". On an average dairy cattle requires 2kg concentrate daily and monthly expenditure on concentrate feed is Rs. 1000 /cow. Azolla feeding can minimize expenditure on concentrate feed in tune of 25-40 %. It can be incorporated at the rate of 0.5 kg/cow /day which will saves average cost on concentrate feed by Rs. 13.55/cow/day i.e. Rs. 400-450/cow/month.

2.A.3.12 Use of sprouts in cattle feeding: The use of sprouted Soybeans, lentils, green peas, black-eyed peas, cow peas, chick pea garbanzos, pigeon peas, wheat, oats & corn are proved beneficial for overall cattle health and production performance. Generally, the sprouted legumes have 2.5 times weight after sprouting due to the absorption of water. In sprouts, the grain's minerals get converted into the chelated form, which absorbs well in the body. Sprouts are a great source of proteins due to availability and an increased percentage of amino acids. These important factors are easily absorbed in the body. Sprouts have many vitamins, mainly vitamins A, B and K are increased to 200 – 600% versus the non-sprouted seed and sprouts have many types of enzymes, which help the

digestion process. Antioxidants react with the toxins produced during the digestion and deactivate them.

Sprouted cereals/ legumes with incremental availability of nutrients:

Proteins 30 % more	Vitamin A 285 % more
Calcium 34 % more	Vitamin B 1 208 % more
Potassium 80 % more	Vitamin B 2 515 % more
Sodium 690 % more	Vitamin B 3 256 % more
Iron 40 % more	Vitamin K much more
Phosphorus56 % more	

Advantages of sprouts as cattle feed

a. **Reduction in cattle feed expenses:** Cattle feed expenses have been reduced by 30 to 50%. Sprouted grains give 2 to 2.5 times the increased weight, thus the animals get a good return in less quantity.
b. **Increase in milk yield:** The animals are getting chelated minerals, required proteins, and enzymes from sprouts, which has produced an increased milk yield of 10-15%. The increased yield began on about the 2 or 3 day of sprout feeding.
c. **Enhancement in milk quality:** Milk Fat and SNF (solids not fats) increased effectively. Amino acids help to boost the fat percentage whereas the chelated minerals in sprouts contribute to SNF rise.
d. **Improved animal health:** Cattle exhibited improved glaze to hide and the animals looked healthier. Sprouts have had positive effects on fertility with an increase in the percent conception rate. Acidity is one of the major factors which decreases the profitability of milk production. The cow dung shows healthy symptoms of digestion. As animals are fed more concentrate & fewer fibers acidity tends to increase. To control acidity, sprouts act very effectively. Many enzymes, minerals, vitamins, essential amino acids etc. all are useful to maintain the normal digestion environment in the animal body. Thus after feeding sprouts the dung which was loose became thick.

Success Stories:

Mr. Dhanaji Jyotiram Jadhav: Village-Adarki, Dist-Satara (MS): I had started the sprouts feeding which reduced expenses on cattle feed. Earlier, the cost of one dairy animal feeding was Rs.66, which reduced to Rs. 32 after feeding of sprouts. So there is net saving of Rs.32on feed cost. Apart from the milk yield is increased by 1.5 lit/ animal, which gave benefit of Rs. 24. The fat is increased by two points and has additional benefits of Rs.7 @ 0.20 per point of fat for total milk. Thus,

I received gain of Rs.63 net per cow after feeding the sprouts. Initially, I did experiments on two cows only but after getting positive results I have started sprout feeding for all herd.
Mr. Vivek Shinde: Village-Thakurki, Dist- Satara (MS): I had started sprouts feeding to two cows out six in my herd, earlier the cost of feeding of one cow was Rs. 45, feeding of sprouts is costing only Rs.35. It resulted in increase in milk yield by 1.75 lit per cow, which gave benefit of Rs.32. Apart from, fat is increased by two points, which gave additional Rs. 5. Thus, I received total benefit of Rs. 46 per cow along with improved health of cows. Unfortunately, eight days after, my farm was affected with FMD disease, but it was strange to note that sprout-fed cows were not affected with FMD due to improved health and enhanced immunity.

2.A.3.13 Supplementation of crop residues with unconventional feed resources

The non-conventional feed resources (NCFR) refer to all those feeds that have not been traditionally used in animal feeding and or are not normally used in commercially produced rations for livestock. NCFR include commonly, a variety of feeds from perennial crops and feeds of animal and industrial origin. The inclusion levels in the animal diets depend on species, physiological status, nutritive value and incriminating factors present, if any.

Constraints in utilization of non-conventional feed resources

a. Limited knowledge on the chemical composition and feeding value of residues: Most of the by-products nutrient composition is known. But most of these have toxic/anti-nutritional factors which have to be identified, characterized and quantified. The detoxification methods have been developed for many, but most of them are not cost effective or not easy for field application. Little is known about long range effects of these toxic factors on animal health and productivity.
b. Non availability of these materials in large quantities: The availability and production of these feed resources is scattered and in some cases the quantity produced is low especially for processing.
c. The availability is restricted to a season in the year. There is no sufficient storage facility during the season of availability.
d. Lack of managerial and technical skills to utilize the feeds for livestock feeding
e. Processing difficulties: Difficulties in collection, handling, transportation and processing of these feeds such as high-moisture feeds, low density feeds.

2.A.4 LET'S SUM UP

In today's scenario to make livestock production profitable and economical it is essential to explore and utilize the new/ alternate feeds, even available in small quantities region-wise, adopt sustainable technologies like complete diet system, ration balancing and growing of hydroponic fodder so that can meet the requirement of feeds for livestock and reduces the competition between human and livestock for common food grains. Precision feeding of animals is need of hour for optimizing the productivity, improve quality of products and reduce the ill effects on environment. Judicial use of land and water resources for sustained animal husbandry practices is a must.

2.A.5 CHECK YOUR PROGRESS

1. What are the advantages of formulation of rations?
2. What are the advantages of feeding processed complete diet?
3. State the importance of Area Specific Mineral Mixture (ASMM)?
4. State the different fodder preservation techniques?
5. What are the advantages of growing cattle feed hydroponically?
6. State the role of sprout feeding in cattle?
7. What is the fodder and concentrate requirement for a lactating cow?

2.A.6 FURTHER READINGS/REFERENCES

1. Handbook of Good Dairy Husbandry Practices, NDDB available at https://www.nddb.coop/sites/default/files/pdfs/Handbook-of-Good-Dairy-Husbandry-Practices.pdf
2. Nutritive Value of Commonly Available Feeds and Fodders in India, NDDB available athttps://www.nddb.coop/sites/default/files/Animal-Nutrition-booklet.pdf
3. Feeding of Dairy Cattle and Buffalo-Small-Scale Dairy Farming Manual, FAO available at http://www.fao.org/3/t1265e/t1275e01.htm

UNIT 2: SUSTAINABLE LIVESTOCK PRODUCTION
B. ANIMAL HEALTH MANAGEMENT

Highlights of the Unit

- Objectives
- Introduction
- Importance to livestock diseases of production and trade
- Animal health management
- Factors influencing health and disease management in livestock
- Production system
- Disease control measures
- Tools for dealing with a disease emergency
- Advances in disease prevention
- Let's sum up
- Check Your Progress
- Further readings/ references

2.B.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Understand the economic importance of disease management
- Understand the various strategies to be adopted for prevention and control of animal diseases

2. B.1 INTRODUCTION

Human kind relies on agriculture and animal husbandry for food. Still, today over 20% of animal production loses are linked to animal diseases. By 2050 the world's population will have reached nearly 10 billion people. More than 70% is the rise in demand for animal protein expected between now and 2050.The subsequent increase of animal production will create new challenges including in the field of disease control. In modern production systems, the most economically limiting diseases are multifactorial enzootic health disorders.

The single biggest advance in animal health in the last 25 years has been the paradigm shift from treatment of clinical illness to disease prevention. Epidemiology has been a critical new influence and tool to describe and quantify the interconnected risk factors that produce disease. Determinants of disease are host, agent and environment.

The principle 'Prevention is better than Cure' seeks to change the focus from one of post-event management and treatment of disease, to one that promotes animal health as a driver of optimized production and improved margins for producers that can provide the best quality food for consumers. Managing disease in the individual or the national herd has traditionally been seen as a 'cost center' or necessary/ inevitable input to production that adds cost and thus should be reduced as much as possible. Animal health management by contrast is to be seen as a positive input investment that will fine-tune and optimize the efficiency of the animal as a producer of food and maximize the returns from the expenditure invested in other farm inputs such as feed, genetics etc.

Preventive veterinary medicine has advanced and developed over the years – such as with the use of anthelmintic and vaccines and the development of herd health plans. Prevention, rather than cure is additionally of particular significance beyond the farm gate - in the context of two major global societal issues – climate change and the worsening situation with regard to antimicrobial resistance. Redefining disease more broadly, to include subclinical conditions, any factor that limits animal or herd performance might be considered a component of disease. Traditional veterinary medicine is focused upon diagnostics and therapeutics of the individual animal. Assuming that if all the sick animals are handled properly, a healthy herd will result. Production medicine focuses upon the underlying herd management system with the assumption that if the production system that produced the problem is fixed, a healthy herd will result.

2. B.2 IMPORTANCE TO LIVESTOCK DISEASES OF PRODUCTION AND TRADE

Infectious animal diseases can affect livestock trade in two important ways. Firstly, there are the so-called Trans-boundary Animal Diseases (TADs) that have the capacity for rapid spread over long distances and are feared by countries that have never had them or have eradicated them. For this reason they are highly trade-sensitive and countries that are free of them require assurances that they will not import them when they import live stock or livestock commodities. Secondly, there are diseases, including TADs, which affect animal production and consequently reduce the amount and quality of animals available for trade. At the subsistence level of livestock production, where trade may not be an important issue, these diseases can jeopardize household food security. In poor mixed farming systems livestock are needed for crop production and if they are not there to provide manure and traction, families may not have enough to eat.

2. B.3 ANIMAL HEALTH MANAGEMENT

Animal health management has been defined as the promotion of health, improvement of productivity and prevention of disease in animals within the economic framework of the owner and industry while recognizing animal welfare, food safety, public health and environmental sustainability.

The enzootic health disorders are primary limiting factors in health. These disorders are present at variable levels in most herds. Their prevalence is influenced by the factors belonging to the farming system itself. Their consequence is primarily a decrease in the productive efficiency of the herd. Farmers can underestimate this aspect of the disease. The economic significance of such disorders might be high because of the financial vulnerability of most intensive production systems. Management of health in this context has to be undertaken on rational procedures according to both economic factors and farmer's preference regarding health management decisions.

The concept of "Integrated animal health management" relies in building and validating integrated holistic environmental and systems approach including "pathogens" and "hosts" as animals in "production" systems.

All the measures to prevent and control diseases more efficiently can be potentially integrated. The ultimate goal is to develop both the necessary elements of control systems (e.g. management procedures / biosecurity; vaccines; disease resistant genotypes; feeding systems, etc.) and the cost-effective approaches required to combine these elements into integrated systems for disease prevention and control.

There are four major issues that influence animal health management:

a. The type of animals involved
b. The production system
c. The diseases that need to be managed
d. The options available for managing the diseases.

Table 1. Common animal diseases

• Anthrax • Black Quarter • Hemorrhagic Septicemia • Foot and Mouth Disease • Rabies (Mad dog disease) • Blue tongue • Pox • Brucellosis of Sheep	• Tetanus • Listeriosis • Campylobactor Abortion • John's disease • Bovine Ephemera Fever • Rinderpest • Mastitis • Foot rot • Bovine Rhinotracheitis	• Piglet diarhhoea or scour PPR TGoat Plague) • Babesiosis (Tick Fever) • Theileriosis • East Coast Fever • Ringworm • Milk Fever • Calf Scour • Lesions • Ketosis

2.B.4 FACTORS INFLUENCING HEALTH AND DISEASE MANAGEMENT IN LIVESTOCK

a. Species: The diseases to which an animal is susceptible depend first and foremost on its species. Foot and mouth disease (FMD) targets all cloven-hoofed species, i.e. important domestic livestock species as well as numerous wild species. Not all the

cloven-hoofed species are equally susceptible. Cattle and pigs develop the most prominent clinical signs; sheep develop subtle lesions that may easily be overlooked and they can therefore spread the disease undetected.

b. **Breed:** Among domestic animals, breed has a strong influence on disease susceptibility and therefore on disease management.
c. **Age and stage of the production cycle:** Age, sex and stage in production cycle influence susceptibility to many diseases and how they can be managed. In general, young animals are more susceptible to infectious diseases because immunity usually becomes stronger over time. On the other hand, young animals are less susceptible to certain tick-borne diseases like bovine anaplasmosis, which causes more severe disease in mature cattle. Young animals that do not get colostrum soon after birth are particularly prone to infections. Diseases that affect reproduction are naturally influenced by sex, with some affecting the female reproductive tract only and others only the male. Sexually transmitted diseases are restricted to sexually active animals and the incidence of venereal diseases can be reduced by using artificial insemination. The stage of production is linked to age but there are additional issues, for example peri-parturient diseases in females that may be linked to a decline in natural immunity around the time of giving birth. Some infectious agents are capable of crossing the placenta and infecting the embryo or fetus in utero and causing abortions, stillbirths, and/or abnormal neonates. Diseases that cause high fever in the pregnant female can result in abortion at any stage of pregnancy without crossing the placenta.
d. **Behavior:** The way in which animals behave is determined by species, breed and individual temperament. Epidemics are more likely to affect herd animals that associate closely as part of their natural behavior than solitary animals or those that congregate in small groups and are territorial and keep a distance from other individuals or groups of the same species. Animals that groom and nuzzle one another are likely to transmit diseases in the process. Fighting is another way in which some blood-borne diseases are transmitted. Curiosity, as displayed by animals can result in exposure to pathogens. Rabies in cattle and horses probably most often results from a bite on the nose from a rabid animal.

2.B.5 PRODUCTION SYSTEM

Production systems have a profound effect on animal health management. They are systems in which animals are raised in varying degrees of confinement and are to a greater or lesser extent fed and tended. Broadly divided into extensive and intensive production systems, the aim is generally to reach production goals in the most cost-effective way possible. The least developed type of production systems, in which animals are grazed on communal land and receive a minimum amount of care and feeding, are usually characterized by low productivity, but may nevertheless be the most cost-effective way for poor owners who do not have good market access. However, commercial farmers expect a better return and large investments have been made in developing animals and production systems that will yield a high return on the investments made.

2.B.6 DISEASE CONTROL MEASURES

Disease control measures, both in routine and emergency situations, are aimed at preventing or reducing to a minimum transmission of the causative agent. The measures adopted will therefore be determined by the way in which the target disease is transmitted. Transmission of contagious diseases can result from direct contact of susceptible with infectious animals, release of the infectious agent into the environment by infected animals, e.g. as aerosols or on to objects that then act as fomites, ingestion of material containing infectious agents, sexual transmission, or bites of infected animals . Vertical transmission to fetuses in the uterus results occurs when pathogens present in the dam are able to cross the placenta. Vector-borne diseases depend on invertebrates, usually arthropods, to transmit the agent.

a. Vaccination: Vaccination is one of the most important tools in the control of the majority of infectious diseases. A good vaccine should achieve reliable and long-lasting protective immunity and be safe in terms of not causing disease or harmful side effects and, in the case of live modified vaccines, not reverting to virulence or mutating to more virulent forms of the agent.

The less demanding a vaccine's cold chain requirements are, the more useful it will be in tropical countries where most of the infectious diseases are found.

Affordability is also important, whether it is to be used by governments in official control programmes or by farmers. Vaccines that reduce the clinical manifestation of the disease but permit circulation of the virus can be useful in limiting economic losses but can be counter-productive for eradication. Fear that this will happen is one of the reasons why vaccination is forbidden when epidemic diseases are introduced into countries where they have been eradicated or have never occurred.

Another reason why vaccination may be forbidden, particularly in exporting countries, is the problem of distinguishing between vaccinated and naturally infected animals. This problem is being or has been addressed for many diseases by the development of DIVA (distinguishing infected from vaccinated animals) technology. This may involve marker vaccines like the subunit vaccine developed for classical swine fever, which is distinguished by an accompanying diagnostic test, or, in the case of FMD, a diagnostic test that identifies non-structural proteins that are not present in the vaccine.

Table 2. Vaccination schedule for farm animals

Sr. No.	Name of Disease	Age at first dose	Booster dose	Subsequent dose
1	Foot and Mouth Disease (FMD)	4 months and above	1 month after first dose	Six monthly
2	Hemorrhagic Septicaemia (HS)	6 months and above	-	Annually in endemic areas.

3	Black Quarter (BQ)	6 months and above	-	Annually in endemic areas.
4	Brucellosis	4-8 months of age (Only female calves)	-	Once in a lifetime
5	Theileriosis	3 months of age and above	-	Once in a lifetime. Only required for crossbred and exotic cattle.
6	Anthrax	4 months and above	-	Annually in endemic areas.
7	IBR	3 months and above	1 month after first dose	Six monthly (vaccine presently not produced in India)
8	Rabies (Post bite therapy only)	Immediately after suspected bite.	4th day	7, 14, 28 and 90 (optional) days after **first** dose.

a. **Chemo Therapy/ Chemoprophylaxis:** Chemoprophylaxis is (mainly bacterial and parasitic diseases) treatment of sick animals and/or prophylactic medication of healthy animals. Most bacterial and parasitic diseases of livestock are susceptible to treatment with suitable medicines. Prophylactic treatment for macroparasitic and protozoal diseases is widespread and generally effective, although there are increasing concerns that environmental pollution with anthelmintic and ectoparasiticides may have severe effects on harmless and beneficial invertebrates like dung beetles. There are also increasing problems with the development of resistance among the target parasites, and holistic control strategies that do not depend entirely on chemotherapy are recommended. The control of tick-borne diseases in endemic areas should be aimed at maintaining endemic stability by allowing a low level of tick infestation that will ensure continuous exposure of the animals to the pathogen to maintain immunity. Effective drugs are available to treat diseases caused by blood parasites, some of which have a prophylactic effect as well. Since therapeutic treatment of large numbers of animals for bacterial diseases may not be practical, the use of antimicrobials in feed, sometimes at sub-therapeutic doses, to control infectious diseases and thereby promote growth has been widespread in intensively farmed animals. It is now being discouraged because of fears of the development of antimicrobial resistance that will make the medicines ineffective and also fears of levels remaining in the animals at slaughter that could lead to resistance in humans.

b. **Biosecurity:** The underlying principle of biosecurity is protection from harm caused by hazards of biological origin. A very broad definition is "The protection of the environment, economy and health of living things from diseases, pests, and bioterrorism". The biological hazards may be restricted to pathogenic micro-organisms or may include all possible hazards including introduction of alien plants and animals, genetically modified organisms and new molecules.
The application of biosecurity measures in the production unit is of cardinal importance to ensure that only healthy animals leave the farm. Essentially, on farm biosecurity means the construction of barriers between the animal and the pathogen. These barriers may be physical, e.g. buildings and screens to exclude vectors; chemical, e.g. disinfectants and prophylactic medicines and pesticides; or biological, e.g. vaccines. The nature of the barriers and how they are implemented depends on the species and the farming system. Stringent biosecurity measures such as showering in and out of the facility and vector exclusion can be applied only in indoor systems such as intensive commercial pig and poultry units.
Measures used to prevent pathogens from being brought into a herd from outside sources (external biosecurity measures) include:
a. Restricted access to the premises where the animals are kept
b. Hygienic measures to ensure that people who need to enter the premises do not bring in pathogens and strict control/decontamination of materials brought onto the farm
c. Keeping a closed herd
d. Introduction of animals only from herds of known health status
e. Quarantine of newly introduced animals
f. Legal requirements for a minimum distance between farms
g. Measures to keep out rodents, birds, carnivores, other livestock; strict separation between domestic livestock and wildlife
h. Strict control over feed; no swill feeding; ensuring that feed and feed sources are wholesome and free from contaminants from manufacture through delivery and storage to consumption
i. Exclusion of vectors (e.g. insect-proof stables, barns)

2. B.7 TOOLS FOR DEALING WITH A DISEASE EMERGENCY

a. **Quarantine:** When a serious infectious disease is suspected in a population of animals, the area or premises is usually quarantined pending confirmation of the disease in order to prevent spread. The area may be a farm, a district or a larger area, depending on the time lapse between discovery of the disease and its initiation as well as the density and distribution of the susceptible animal population and the level of contact within and between herds or flocks.
b. **Movement control:** Movement control is not only an emergency disease control measure. In many states movement control is routinely applied, for example to animals being moved to abattoirs for slaughter, in order to prevent illegal movements of animals that may, for example, have been introduced illegally from another country

or from an infected area in the same country. When there is an outbreak of a highly infectious or trade-sensitive disease, movement control may be more rigorously applied.

c. **Stamping out (culling):** Culling, or stamping out, of infected animal populations is a traditional way of eradicating a disease outbreak as quickly and effectively as possible.

2.B.8 ADVANCES IN DISEASE PREVENTION

a. **Epidemiology:** The concepts, analytic techniques and critical appraisal from epidemiology
constitute one of the greatest contributions to disease prevention.
b. **Transition cow management:** Approximately 75% of disease in dairy cows typically happens in the first month after calving.
c. **Immunology:** Recognition of the importance of immune function in prevention of retained placenta, metritis, endometritis and mastitis.
d. **Cow comfort:** Free stall housing has come to predominate the industry.
e. **Calf health:** Passive transfer of immunity resulted in best management practices.
f. **Tools for monitoring:** Rapid, relatively inexpensive metabolic tests which can be run—on – farm, in local veterinary clinics or cow side have become available.
g. **Udder Health**
    - Plan for Mastitis control
    - Practice of post milking teat disinfection.
    - Application of long-acting antibiotic therapy at drying,
    - Milking machine function.
    - Early detection and treatment of clinical cases.
    - Culling of chronically infected cows.
    - Detection of subclinical cases.

2.B.9 LET'S SUM UP

Animal health management is all about making a veterinarian becoming more of a consultant to the food animal industry. Prevention is better than cure. Disease control programs help in sustaining production performance of farm animals and prevent massive suffering and death. It significantly contributes towards public health also, as 80% of diseases are zoonotic in nature. No single or foolproof method of control is available for a particular disease but combination of such methods is necessary in most instances. Nevertheless, some of the diseases have not been controlled successfully in developing countries because of inadequate veterinary services, political instability, lack of support from local population and inefficient financial and technological assistance. In addition to these approaches, proper legislation for disease notification and control of diseases is necessary towards controlling and final eradication of livestock diseases. Although mainly, the government funds livestock disease programs, community support is the bottom line for their success.

2.B.10 CHECK YOUR PROGRESS

1. What are the preventive measures to be taken at the farm to maintain the health of the livestock?
2. What are the strategies to be adopted for control of infectious diseases?

2.B.11 FURTHER READINGS/ REFERENCES

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UNIT 2: SUSTAINABLE LIVESTOCK PRODUCTION

C: PROCESSING/ VALUE ADDITION IN LIVESTOCK PRODUCT

Highlights of the Unit

- Objectives
- Introduction
- Status of Indian dairy industry
- Status of Indian meat industry
- India's poultry sector
- Milk processing and value addition
- Meat processing and value addition
- Type of processed meat products
- Prospect of processing and value addition in livestock commodities
- Challenges in processing and value addition in livestock commodities
- Government initiatives to promote food processing and value addition in livestock commodities
- Let's sum up
- Check Your Progress
- Further readings/references

2.C.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Status of Indian dairy and meat sector
- Processing and value addition in livestock commodities
- Prospect of processing and value addition in livestock commodities

2.C.1 INTRODUCTION

The food processing sector is growing at a faster rate than agriculture sector. During the last 4 years ending 2015-16, food processing sector has been growing at an Average Annual Growth Rate (AAGR) of around 2.88 per cent. The preferences and practices in consumption are changing very fast in favor of processed food. It is going through major transformations; specialized food chains and on-demand food subscriptions are new trends. This implies that more and more agriculture and livestock produce is now getting processed. Food processing industry in India is increasingly seen as a potential source for driving the rural economy as it brings about synergy between the agriculture, industry and consumer.

A well-developed food processing industry is expected to increase farm gate prices, reduce wastages, ensure value addition, promote crop diversification, generate employment opportunities as well as export earnings. Besides the obvious opportunity of adding value through food processing and packaging, there are several other

possibilities in the areas of Agri-services, farm mechanization, post-harvest management, quality testing services, and supply chain management. These interventions have immense potential to raise farm incomes as well, contributing to an area of national priority.

The Ministry of Food Processing Industries, GOI also promoting food processing and value addition in big way through development of modern infrastructure and common facilities to encourage group of entrepreneurs to set up food processing units based on cluster approach by linking groups of producers/ farmers to the processors and markets through well-equipped supply chain with modern infrastructure. The milk, meat and eggs are major commodities of livestock sector being produced by the farmers in high quantity but the processing and value addition remained in dormant states especially in case of meat and eggs. Development of established value chain in these commodities is need of the hour for sustainability of the sector.

2.C.2 STATUS OF INDIAN DAIRY INDUSTRY

Over the years, India has emerged as one of the world's biggest producers of milk, with the total milk production rising from 122 million Metric Tons in 2010 to 176.4 million Metric Tons in 2017-18. According to Department of Animal Husbandry, Dairy and Fisheries, Govt. of India, Indian dairy sector is estimated to be worth Rs.3.6 lakh Crore which produces 17 % of total world milk production. The Indian dairy industry is divided into the organized and unorganized segments. The unorganized segment consists of traditional milkmen, vendors and self-consumption at home, and the organized segment consists of cooperatives and private dairies. As per the Annual Report for FY17 of Dept. of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture & Farmers Welfare, GOI, co-operatives and private dairies still procure only about 20% of the milk produced in the country, while 34% is sold in the unorganized market and about 46% is consumed locally. However, in most of the developed nations, 90% of the surplus milk is processed through organized sector. Indian organized dairy sector is required to strengthen the procurement and processing line to scale up for value added market. On the other side, Industry is looking health aspects very strictly and focus is shifting on nutrition in the milk and value-added products which unorganized market is not serving. Strong demand for dairy products encourages continued expansion in the bovine herds as higher dairy prices spur the development of more commercial farms.

2.C.3 STATUS OF INDIAN MEAT INDUSTRY

The meat sector in India remained as low-priority area till the 10th five-year plan. Only during the 11th five-year plan (2007-12), modernization of slaughterhouses, value addition and infrastructure development has received attention. Meat production is estimated at 6.3 million tones, standing 5th in rank of world's meat production and account for 3 % of the total world meat production of 220 million tones. Buffalo in India contribute about 31 % of total meat production. The contribution by cattle, sheep, goat,

pig and poultry is 31%, 5%, 10%, 10% and 11% respectively. The share of bovine meat is about 62% as against the small ruminant of 15%. The share of readymade is 77%. In spite of big potential because of large livestock population the meat industry has not taken its due share on account of negative perception although India has acquired number one status in milk production. The meat production is still lagging behind and is at 5thposition.

Indian meat sector is highly unorganized and unregulated compared to many other developed and developing nations. The livestock rearing in India is primarily for livelihood security and not for commercial purpose. Meat production has not received adequate attention by the entrepreneurs, policy makers, scientists and politicians although it is linked with the economic condition of poor farmers and backward communities. Meat production is intimately linked with quality leather production in which India has acquired second position in the world after Italy. If proper attention is given by the Government both meat and leather can also acquire number one position in the world like milk. One of the major constraints in achieving the goal is the hygienic meat produced for domestic market in the traditional slaughter houses causing environmental pollution and another is that the industry is with the traditional people who have not been exposed to modern technology for domestic market

However, in the recent days commercial rearing of livestock is raising because of market development, tax incentives and demand for animal proteins. This has resulted in gradual increase of intensive rearing of animals especially sheep and goats in few states like Tamil Nadu and Karnataka. India has a huge livestock wealth and ranks 1st in the world for buffaloes and goat population. India also has 2nd and 4th largest number of sheep and chicken in the world. Bovine herd expansion is supporting more meat production in India.

2.C.4 INDIA'S POULTRY SECTOR

India's poultry sector represents one of the biggest success stories of the country over the past decade. Nearly 20 million farmers are employed in poultry industry with around 1,000 hatcheries operating across India. While agricultural production has been rising at the rate around 2% per annum over the past two to three decades, poultry production has been rising at the rate of around 8-10% and value-added poultry products sector is growing at more than 10%. The domestic market has displayed increasing buoyancy, owing to a growing rural market based on lower feed and poultry prices, growing disposable income and increased awareness of new technologies and mechanizations in the sector. Nevertheless, urban demand still accounts for 80% of domestic consumption. South India accounts for majority of total poultry production and consumption in the country. Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Maharashtra in the west and Haryana, Punjab in the north are key regions in this aspect.

2.C.5 MILK PROCESSING AND VALUE ADDITION

As per Rabobank analysis, in 2016-17 Indian dairy market was largely divided into Liquid Milk (64 per cent), Value Added Products (25 per cent), Ghee (7 per cent) and Milk Powder (4 per cent). Value Added Products in dairy segment is further growing at 15 per cent to 20 per cent year on year that has varied products like cheese, UHT milk, curd, baby Foods, Ice-cream, Butter, Flavored Milk and Dairy Whitener. While packaged liquid milk is to remain a key driver in the Indian dairy industry.

Table 1. Value added dairy products

Acidophilus Milk Ammonium Caseinate Butter Butter Fat Butter Oil Butter Solids Buttermilk Buttermilk Powder Calcium Caseinate Casein Caseinate (in general) Cheese (All animal-based) Condensed Milk Cottage Cheese Cream Curds Custard Delactosed Whey Demineralized Whey Whey Protein Concentrate Nonfat Milk Nougat Paneer	Evaporated Milk Ghee (see page 109 in Go Dairy Free) Goat Cheese Goat Milk Half & Half Hydrolyzed Casein Hydrolyzed Milk Protein Iron Caseinate Lactalbumin Lactoferrin Lactoglobulin Lactose Lactulose Low-Fat Milk Magnesium Caseinate Malted Milk Milk Milk Derivative Milk Protein Milk Solids Natural Butter Flavor Potassium Caseinate	Pudding Recaldent Rennet Casein Sheep Milk Sheep Milk Cheese Skim Milk Sodium Caseinate Sour Cream Sour Milk Solids Sweetened Condensed Milk Whey Sweet Whey Whey Protein Hydrolysate Whipped Cream Whipped Topping Whole Milk Yogurt Zinc Caseinate Whey Powder Dry Milk Powder Dry Milk Solids Milk Fat Milk Powder

Indian consumer is becoming more health conscious and demand for healthier products with natural, organic and an Ayurveda ingredient is increasing. Changing consumer lifestyle, increasing number of working women and increasing personal disposable incomes are leading to an increase in demand of value added dairy products. Smaller packs of packaged dairy products are being aggressively marketed for the second and third tier markets to deepen a brand's penetration and increase the volume in the country.

The increasing numbers of players in the dairy sector are focusing their strategies towards the untapped semi-urban and rural regions, which offer significant opportunities for growth. During the last five to ten years, India has seen dramatic shift towards consumption of value-added products such as cheese, yoghurt, UHT (ultra-heat treatment) milk, flavored milk, and whey. These value added products are growing at 25-30% per annum. To tap the advantages of the changing consumer food preferences, most organized players are expanding product portfolios in the value-added segment. This segment offers high growth potential and better margins versus the liquid milk and Skimmed Milk Powder (SMP) segment.

2.C.6 MEAT PROCESSING AND VALUE ADDITION

Meat processing includes all those processes that alter the form of fresh meat in preparation for consumption. In the broadest sense, this includes curing, smoking, canning, cooking, freezing, dehydration, fermentation, production of intermediate-moisture products, and the use of certain additives such as chemicals and enzymes. This definition excludes cutting, grinding, and packaging of fresh meat at retail stores and at homes. Examples of processed meat include hot dogs (frankfurters), ham, sausages, corned beef, and biltong or beef jerky as well as canned meat and meat-based preparations and sauces. The main purpose of meat processing is as follows.

- Production of value-added products and provide variety of meat products.
- Utilization of carcasses profitably and to utilize different by-products.
- Combining and complimenting different meats with advantage.
- Incorporating non-meat ingredients for quality and economy.
- Preservation, transport and distribution to larger populations.
- Facilitation of export of meat products and compete with imports.
- Promoting entrepreneur ventures and employment.

The processing and value addition of meat in India remains less than 2.0% with the exception of poultry where 7.2% of meat undergoes processing. The Indian market is witnessing a revolutionary change and several multinational companies are introducing globally known products in the Indian markets. There has been an increase in both, the number of players in the frozen products segment and the availability of convenience and ready to eat meat products. Compared to broiler industry which is growing at 12-15% per annum, the ready to eat meat products segment is growing at more than 20% in India. Even though, cultural patterns rather than income dominate meat consumption in India, the ready-to-eat meat sector is growing with consumer affluence.

Large meat processing companies as mentioned below have entered into meat processing and catering to the demands of certain percentage of population. KFC currently operate 625 stores in the country and aiming to open 1000 stores in about 100 cities. Suguna Daily Fresh is currently having 150 stores and planning to open 500 retail outlets in the next 3 years. Suguna Foods, which currently runs one *"Suguna Crisp & Crunch"* outlet, plans to open 2000 quick service restaurants across India in the next 5

years. Venky's XPRS has opened its outlets in Pune, Mumbai and Hyderabad and planning to expand. Godrej-Tyson has created the infrastructure to market poultry products in most of the western and southern cities in India. But such initiatives in sheep, goat and large animal meat is almost absent.

The evolution of modern retail outlets with better packaging, labeling, chilling and cold chain facilities will hopefully address the drawbacks of the existing situation. Realizing the Indian quick service restaurant market which is worth $ 13 billion, several food majors viz, Denny's Corp, Pollo Tropical Carrols Restaurant, Applebee's and Johnny Rockets, Wendy's, etc. are entering India. Few large players like METRO, SPAR Hypermarket, Walmart, etc. have already entered into retail sector.

Table 2. Value-added meat products producers/manufacturers in India

• Godrej-Tyson Foods: Real Godrej Chicken, Yummiez • Suguna Daily Fresh • Venky'sxprs • Alchemist: Republic of chicken • Amrit-Fresco pollo • Vista Processed Foods Pvt. Ltd., Maharashtra • Meat Products of India Ltd., Kerala • Arambagh's Chicken • Zorabian Chicken	• Baramati Agro: Delicious Chicken • Al-kabeer • Allana-Saffa • CP Foods: Five-star chicken • Darshan Foods Pvt. Ltd.: Meatzza • Sumeru Frozen Foods • The Meat Master: Cock A Doodle • BFI Foods India Ltd.: Chicking • ChicXpress • Lite Bite Foods • Porna Chicken (SKM's)

India has around 4000 registered slaughter houses, 25,000 unregistered premises where animals are slaughtered for domestic consumption, 66 APEDA approved abattoir cum meat processing plant and 38 other meat processing plants for export of meat. In addition, we also have 4 poultry processing plants and 4 egg processing plants approved by Export Inspection Agency. The meat produced in India for the domestic market is sold as hot meat (pre-rigor meat without any chilling). Goat/sheep meat is marketed in villages by slaughtering one or two animals once in a week or during special occasions by a group of people joining together and sharing the cost of the meat so obtained. In the big towns and cities, slaughtering is performed in designated abattoirs or slaughter houses and most of the meat is consumed on the same day or kept in a refrigerator in the households. Poultry meat is mostly sold by slaughtering the live birds in the presence of the consumers. However, there are a few modern processing plants where poultry is slaughtered, chilled, packed and frozen chicken is sold in big cities. Compared to other meats, reasonable amount of poultry meat undergoes further processing into a range of value-added meat products like sausages, patties, lollipops, breaded nuggets, fried drumsticks and various traditional meat products for different markets.

Table 5. Permitted levels of preservatives in meat products (FSSAI, 2011a)
(Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011)

Preservative	Processed meat product	Permissible limit
Sulphur dioxide	Sausages	450ppm
Sodium Nitrite	Pickled meat and bacon	200ppm
Sodium Nitrite	Meat Food Products	200ppm
Sodium Nitrite	Corned Beef	100 ppm
Hydroxypropyl Methyl Cellulose	luncheon meat and poultry products	1.0%
Gluconodelta Lactone	Cured meat or meat products	5,000
Ascorbic acid	Corned beef, Luncheon Meat, Cooked Ham, Chopped Meat, Canned Chicken, Canned Mutton	500ppm
Phosphates	Luncheon Meat, Cooked Ham, Chopped Meat.	8000ppm

2. C.7 TYPES OF PROCESSED MEAT PRODUCTS

- Comminuted uncured meat products
- Cured and smoked meat products
- Fermented meat products
- Dried meat products
- Restructured meat products
- Emulsion based meat products
- Enrobed products
- Functional meat products
- Ethnic meat products
- Extruded meat products
- Canned/retort pouch meat products

Table 6. Microbiological standards for processed meat products (FSSAI, 2011b) (Food Safety and Standards (Food Products Standards and Food Additives) Regulations, 2011)

Meat product	Microbial Count						
	Total Plate Count	***E. Coli***	***Staphylococcus aureus***	***Clostridium perfringens and Clostridium Botulinum***	**Yeast and mold count**	***Salmonella***	***Listeria monocy togenes***
Frozen mutton, chicken, goat and buffalo meat	100000/ g	100/ g	100/ g	30/ g	1000/ g	Absent in 25 g	Absent in 25 g
Canned corned beef	1000 / g	Absent in 25 g	Absent in 25 g	Absent in 25 g	NIL	Absent in 25 g	NIL
Canned luncheon meat	1000 / g	Absent in 25 g	Absent in 25 g	Absent in 25 g	NIL	Absent in 25 g	NIL
Canned cooked ham	1000 / g	Absent in 25 g	Absent in 25 g	. Absent in 25 g	NIL	Absent in 25 g	NIL
Canned chicken	1000 / g	Absent in 25 g	Absent in 25 g	. Absent in 25 g	NIL	Absent in 25 g	NIL
Canned mutton and goat meat	1000 / g	Absent in 25 g	Absent in 25 g	. Absent in 25 g	NIL	Absent in 25 g	NIL

2. C.8 Prospect of Processing and Value Addition in Livestock Commodities: Protein malnutrition is an emerging challenge among human population in developing and under developed countries. Easiest way through which protein malnutrition can be corrected is through promoting consumption of animal protein sources like milk and milk products. Of the total new born babies in India, average birth weight of 40 percent newborns was below 2 kilograms. Indians spend 40 percent of his daily income for food alone of which 28 percent for animal protein sources like milk, milk products, meat, egg,

fish and their products in urban and 26 percent in rural areas. With regard to vegetables, pulses and fruits it is 26 percent and 24 percent respectively. So there is huge demand for dairy products within the globe. But supply is limited. Major challenge is to correct the supply demand mismatch and to exploit the increasing market potential across the World.

Table 3. Per Capita Availability & Deficit/ Surplus

Food Item	ICMR recommendations	Per Capita Availability	Per Capita Deficit/ Surplus
Milk	300 gm/day/ Person	**322** gm/day/ Person	+ 22 gm/day/ Person
Egg	180/year/ Person	63 /year / Person	- 117 /year / Person
Meat	10.95 kg /year / Person	5 kg /year / Person	- 5.95 kg /year / Person

The major driving force for fast growth of value-added dairy products are

- **Affordability:** Dairy beverages like buttermilk, lassi and flavored milk are priced lower or equivalent to carbonated drinks, and much cheaper than juices or other health drinks
- **Quality**: The overall quality of milk has improved dramatically over the years, as direct milk procurement has increased, thus cutting off the middle men, investments in plant and machinery, systems and processes to ensure a high sense of manufacturing hygiene
- **Demand for Healthy foods and beverages growing**: The Indian consumers are wanting more healthier food and beverage options to consume, and are also willing to pay a premium ranging from 20%-80%, as per a recent study conducted by research agency Nielson

There is huge potential for ready to eat and ready to cook food products. In the changing environment, women are not confined to the kitchen, but they are emerging as home managers. Food outsourcing is an emerging area across the World. On an average 65% Indians above 60 years of age is either suffering from hypercholesteremic or diabetes. They require customized dairy products. Children require high calorie dairy products with increased quantity of protein and fat. Cheese is having good market potential in the international market. But India unable to tap the export potential of cheese due to its poor-quality standards. The organized cheese market including its variants like processed cheese, mozzarella, cheese spreads, flavored and spiced cheese, is valued at around Rs. 4.5 billion.

Processed cheese at 65% of the overall market is Rs. 3 billion. Cheese spread has a market share of around 30% of the total processed cheese market. The market for cheese cubes, slices and tins is growing at an annual rate of around 15%. Gujarat Cooperative

Milk Marketing Federation (GCMF) with the Amul brand continues to be the main operator in the branded cheese market in India. It pioneered the market for processed, branded cheese and developed the technology to make cheese from buffalo milk even though across the world cheese is made from cow milk.

The Market for meat based processed ready to eat food products is rapidly increasing. The total market for non-vegetarian value-added products (for example; nuggets, kababas, etc.) is Rs. 150-180 crore, majority of which are chicken-based products.

Table 4. Livestock Product Consumption Projection in India by 2030 (%)

Commodity	Proportion of change due to change in food habit & consumption rates (%)	Proportion of change due to change in population (%)	Cumulative % Change
Milk	48.1	32.9	81.0
Mutton	38.8	46.0	84.8
Beef	16.4	77.2	93.6
Pork	54.1	24.6	78.7
Poultry	68.4	43.7	112.1
Eggs	145.2	33.0	178.2
Total	**61.83**	**42.90**	**104.73**

2.C.9 CHALLENGES IN PROCESSING AND VALUE ADDITION IN LIVESTOCK COMMODITIES

a. Inadequate market facility and declaration of holidays for milk collection in flush season
b. Lack of assured fodder supplies and high cost of concentrate feed
c. Lack of awareness in farmers about value addition
d. Limited access to veterinary services breeding and health
e. Inadequate cold chain and lack of transport facility for raw milk
f. Improper practices in milk and meat production resulting in poor quality products
g. Myths about meat consumption and half-truths in the media against meat consumption
h. Insanitary and unhygienic conditions of the slaughterhouses and the meat shops
i. Lower carcass weight and dressing percentage of food animals due to the slaughter of spent / aged animals.
j. Indian consumer prefers fresh meat, resulting in less demand for frozen meat
k. Diseases such as Foot and Mouth Disease (FMD) are a major concern

l. Subsidies in developed countries, stipulation of Sanitary and Phyto Sanitary (SPS) measures, and increasing cost of production and inputs as compared to competing countries
m. Non availability of good quality livestock in the open market
n. Overcrowding of food animals during transport resulting into inferior meat quality

2. C.10 GOVERNMENT INITIATIVES TO PROMOTE FOOD PROCESSING AND VALUE ADDITION IN LIVESTOCK COMMODITIES

National Meat and Poultry Processing Board (NMPPB): NMPPB was established in 2009 with mandate to oversee the growth and further promotion of meat and poultry sector in the country. NMPPB was to address issues related to production of hygienic, safe and wholesome meat and meat products.

Mega Food Park Scheme: Mega Food Parks Scheme, being implemented since 2008, aims to create a modern food processing infrastructure for the processing units based on a cluster approach and on a hub and spoke model in a demand driven manner. The scheme intends to facilitate establishment of an integrated value chain, with food processing at the core and supported by requisite forward and backward linkages.

Scheme for Integrated Cold Chain and Value Addition Infrastructure: It was launched during 2008 and intended to provide integrated cold chain, preservation and value addition infrastructure facilities without any break, from the farm gate to the consumer in order to reduce post-harvest losses.

Scheme for Setting up/ Modernization of Abattoirs: Ministry had launched a comprehensive scheme for modernization of abattoirs across the country in the year 2008-09 to give a fillip to up gradation of technology to ensure hygienic slaughtering of animals for meat processing. The scheme provides for implementation of projects with the involvement of local bodies (Municipal Corporations and Panchayats) / Public Sector Undertakings / Co-operatives / Boards under Government and private investors on PPP basis. Regulatory functions continue to be discharged through local bodies. Under the scheme, so far 12 abattoir projects have been completed and 25 projects are under implementation.

Scheme for Technology Up-gradation/ Establishment/ modernization of food

Processing Industries: Ministry has been implementing the scheme since 9th Five Year Plan (1997-2002).

Scheme for Setting up/ Up-gradation of Quality Control/ Food Testing Laboratories

Manufacture of quality food requires strict adherence to various aspects of Total Quality Management (TQM) such as quality control, quality system and quality assurance in an integrated fashion. These are vital for reaching the world market as well as to avoid being swamped by imported food items with the increase in awareness about the quality of

food products particularly among the growing middle class, there is now a more evolved class of domestic consumers for whom quality, nutrition and safety are non-negotiable. Ministry has been implementing the scheme.

2. C.11 LET'S SUM UP

There is increasing significance of poultry and livestock products in the context of diversifying farm and non-farm activities in the agriculture sector to increase livelihood security. The demand for meat and meat products continues strong in India and will be the key driver for livestock sector. Emerging consumption of convenience and value added meat products will not only diversify the food production system, but also will provide huge employment opportunities to large number of micro, small and medium scale entrepreneurs. However, huge investment is needed in India's animal production sector, especially meat sector, in order to supply the country with reliable, safe and high quality meat and meat products. Rapid consolidation in meat processing, more vertical integration and large number of smaller processing units will be the key trends.

2. C.12 CHECK YOUR PROGRESS

1. Describe the status of Indian dairy, meat and poultry industry?
2. State the opportunities in milk and meat processing and value addition?
3. What are major challenges in milk and meat processing and value addition?
4. What are the major government initiatives for promotion of processing and value addition in milk and meat sector?

2. C.13 FURTHER READINGS/ REFERENCES

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UNIT 2: SUSTAINABLE LIVESTOCK PRODUCTION
D: LIVESTOCK EXTENSION AND ADVISORY SERVICES

Highlights of the Unit

- Objectives
- Introduction
- Livestock extension
- Need for a specialized livestock extension service
- Status and issues of extension services in livestock sector
- Livestock extension delivery institutes
- Constraints in adoption of extension services
- Strategy for revamping animal husbandry extension
- Let's sum up
- Check Your Progress
- Further readings/references

2.D.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Status of extension services in livestock sector
- Constraints in Adoption of Extension Services
- Strategies for effective extension services in livestock sector

2.D.1 INTRODUCTION

In spite of India's highest livestock population in the world, the productivity particularly of ruminants has been extremely low, turning this precious asset of the poor into a liability. The livestock husbandry programme, particularly dairy husbandry is suffering because of low productivity, inferior quality of the products and non-existence of an efficient value chain. Dairy husbandry is the major sector, as over 60% of the rural households maintain large ruminants mostly for milk and partly for bullock power. However, the average milk yield is significantly low - 987 kg per lactation as against the world average of 2038 kg per lactation. This is due to indiscriminate breeding leading to severe genetic erosion, neglect of health care, shortage of fodder and feed resources and lack of awareness among small farmers and poor guidance on good management practices.

Goat and sheep are generally maintained by marginal farmers and landless, who cannot afford to own large ruminants, mostly for meat and partly for milk and wool production. However, most of these small ruminants which are dependent on free grazing without any investment on supplementary feeding and health care, do not make significant contribution to the income. While the demand for meat is expected to grow

by 3-4 folds during the next two decades, the present system of unsustainable husbandry practices, highlights the status of these species, deprived of technological and managerial support.

Poultry is another important sector, where private industries are playing a major role to support farmers in selected hubs across the country. However, most of the small farmers, particularly those living in remote areas are unable to take up this venture. For such farmers, small scale backyard poultry with hardy indigenous breeds can be a source of income, if suitable backward and forward linkages are provided. Piggery also has good scope across the country but the programme is almost under neglect, except in a few North-eastern States. Thus, the entire Animal Husbandry sector is suffering due to low productivity and lack of forward and backward linkages and turning uneconomical for farmers.

Although the livestock sector is registering phenomenal growth, several challenges remain unaddressed. Recent advances in the animal husbandry sector have increased the demand for various livestock services like animal breeding, health care, feed and fodder production, marketing, livestock extension etc. which are provided by multifarious agencies in India.

2.D.2 LIVESTOCK EXTENSION

Among all the services, livestock extension services play an important role to empower farmers with appropriate technological knowledge and skills through various extension education and training programs. For productivity improvement, technology generation, technology dissemination and support services are most critical which need to be geared up. It is further necessary to bring all the stakeholders on a common platform to facilitate optimum contribution by each player to fulfil the goal. Among various stakeholders, livestock keepers are the key players, who have to interact with other stakeholders and initiate suitable actions to enhance the production and profit margins. Unfortunately, most of the livestock keepers being poor, they are unable to tap the potentials of livestock to in- cash the opportunity of meeting the growing demand for milk, meat and eggs, which is expected to increase by 80-100% by 2025. The challenge for the Government and other development agencies is to ensure active participation of small holders in livestock production, instead of allowing large dairy farmers and multi-nationals to capture this opportunity. If we have to ensure production by masses, instead of mass production by the corporates, small farmers must be organized to improve the productivity of livestock, through well planned Animal Husbandry Extension programme across the country.

The Livestock Extension services include transfer of technology and strengthening of various infrastructure and support services, while building the capabilities of the stakeholders. The extension service should aim at assisting farmers through educational process to improve livestock farming methods and techniques, increase production efficiency and income, and enable them to improve their quality of life. The Extension service should enable farmers to identify and analyze their production problems and

increase their awareness on the scope for improvement. It should motivate those who are hesitant and ignorant about new technologies and systems which can improve the production and income. For the semi-literate and poor livestock keepers, the real extension service means hand-holding or mentoring till they adopt good practices and form a part of the value chain to realize maximum benefits.

2.D.3 NEED FOR A SPECIALIZED LIVESTOCK EXTENSION SERVICE

With the livestock sector assuming the important role in the national economy, there is further requirement to improve the present state of livestock sector. Livestock production has been steadily growing, faster than any other agricultural sub-sector, and it is foreseen by 2020, livestock sector will account for more than half of total agricultural output in economic terms. Further, to reach the growth rate of 4 % in the agriculture sector as envisaged in the 11th plan, the growth in livestock sector becomes more essential for which role of extension service especially the information input becomes vital (Chander et al., 2010). Most models try to integrate livestock into general extension systems by providing cross training of crop specialists in the areas of livestock production and vice-versa. But in practice, its availability has been patchy and the course work too short and too class room based (Morton and Matthewman, 1996). This obviously affected the quality of the extension service to livestock owners, which had inhibited them in adoption of modern livestock technology (Rao et al., 1992). Moreover, the highly specialized livestock extension service has different requirements since it has distinct features from crop extension due to longer time-scale of animal production, slower speed of technology development, lack of synchronous of different animals, difficulty in demonstrating merits because of their poor observability, frequently dispersed and non-uniform needs of livestock owners (Matthewman et al., 1997; Rao and Kherde, 1985). Livestock extension services to the farmers have the potential to play the key role in improving livestock productivity but despite of its importance livestock extension has been treated somewhat casually as is evident from the organizational structure, budget and staffing for extension activities both at central and state levels.

Effective Livestock Extension would include:

a. Help farmers to identify their production and marketing related constraints through awareness, exposure, exchange of information among other farmers, extension officers and other stakeholders;
b. Assist farmers to make best use of the technologies and support services through capacity building;
c. Establish linkage with information sources on agricultural innovations, new technologies, market related information such as demand-supply and prices;
d. Build capacities and skills of farmers to empower them to adopt good practices in production for improving production while reducing the risk;
e. Promote Producers' Organizations, to facilitate a platform for value chain and ensure involvement of various stakeholders to improve the production and profitability.

2.D.4 STATUS AND ISSUES OF EXTENSION SERVICES IN LIVESTOCK SECTOR

a. The first and foremost issue regarding livestock extension, there is lack of a livestock extension policy and dedicated administrative structure for livestock extension at center and state level leading to unorganized, sporadic and ineffective delivery of extension services to livestock farmers.
b. The focus of the State Department of Animal Husbandry (SDAH) is on healthcare and breeding aspects of livestock than production.
c. Further the Livestock extension services in India are characterized by five biases that result in neglecting poor rural livestock-keepers. First, many organizations follow only a top-down 'transfer of technology' approach; Second, focus is mostly on cattle and buffaloes, to exclusion of other species; Third, focus is primarily on milk production, neglecting other roles of livestock; Fourth, services are usually concentrated in high potential areas and; Fifth, livestock extension is generally provided by men for men, despite key roles that women play in livestock farming (Matthewman and Ashley, 1996).
d. Currently there is a lack of institutional shift from extension to entrepreneurship in livestock extension activities (Ramkumar, 2014).
e. Conventional dairy extension (has focus on improving production in terms of unit cost involved in feeding, breeding and management) vis-à-vis Commercial dairy extension (with focus on marketing, market rates, value addition, project formulation, licensing, climate change, pollution control, budgeting, sources of funds, insurance, mechanization etc.).
f. In the light of the above challenges, livestock extension professionals need to have or acquire core competencies in extension as well as technical subject matter for effective service delivery.
g. Moreover, the shortage in the number of Veterinary Assistant Surgeons (VASs), who are the middle level livestock extension professionals (Rama Rao et al., 2011; Anon., 2012; Anon., 2013; Sasidhar and Reddy, 2013; Rao et al., 2015), and inadequate competencies among these extension professionals (Matthewman and Ashley, 1996; Delgado et al., 1999; Ahuja et al., 2000; Chander et al., 2010; Hegde, 2010; SAPPLPP, 2012) lead to further deterioration of livestock extension service delivery, which resulted in, only 5.1% of the households being able to access animal husbandry information, whereas, the corresponding figure for agricultural sector was 40.5% indicating gross negligence of livestock extension education activities in the country (NSSO, 2005).
h. To address the above challenges in livestock extension service delivery, the 10th and 11th Planning Commission recommended that, either the states should create a separate wing within the department for livestock extension service delivery (Model-I) or some of the veterinary officers of department may be deputed exclusively for this purpose (Model-II). Accordingly, some of the states came forward and made such arrangements, however in many SDAH the number of extension personnel in separate wing model is meagre and placed mostly either at head quarter or divisional

level. The other model of designated officers for extension, are overburdened with multiple roles and therefore extension remained neglected. Most of the SDAH have not given any induction training on extension management before the placement of such livestock extension officers.

i. Further, poor participation of private sector and inadequate budget for livestock extension activities resulted in weak extension component. The SDAH-as the major stakeholders for delivery of extension services spend only 1-3 % of their budget on extension activities.

2.D.5 LIVESTOCK EXTENSION DELIVERY INSTITUTES

2.D.5.1 Department of Animal Husbandry, Dairying and Fisheries (DADF)- (Now Separate Ministry): DADF is one of the Departments in the Ministry of Agriculture, which is responsible for matters relating to livestock production, preservation, and protection from disease and improvement of stocks and dairy development, and also for matters relating to the Delhi Milk Scheme and the National Dairy Development Board. The Department advises State Governments/Union Territories in the formulation of policies and programmes in the field of Animal Husbandry, Dairy Development and Fisheries. Report of the Working Group on Animal Husbandry and Dairying for the Tenth Five-Year Plan (2002-2007) for the first-time treated livestock extension differently from crop related extension activities, so a separate sub-group was created to address the issues concerning livestock extension activities.

2.D.5.2 State Department of Animal Husbandry (SDAH): SDAH at the state level, the Animal Husbandry Department (AHD) is the major stakeholder as far as livestock productivity is concerned. The AHD with its huge infrastructure, however, is primarily involved in treatment and handling of sick animals for which it has a clear mandate (Singh et al., 2014). With more effective control of serious diseases such as Rinderpest (now eradicated from India) and Newcastle disease and more easily available treatment for many other conditions, animal health constraints are gradually being overcome (Morton and Matthewman, 1996; Gandhi, 1998). The SDAH have the widest mandate for livestock development and are best placed to deliver livestock production. Veterinary functionaries are expected to perform twenty-five multifarious activities in which extension is one (Venkatadri, 2002). They are available throughout the country for livestock owners to consult for information on livestock related issues, organize livestock fairs, shows, camp, competitions and programmes for cattle, poultry, small ruminants and pigs.

2.D.5.3 Directorate of Extension Education: Directorate of extension was set up in 1958 in the wake of launching of Community Development Programmes and National Extension Service throughout the country in 1953. It is the nodal agency in the Department of Agriculture and Cooperation, Ministry of Agriculture for agricultural extension programmes at the national level. Major policy guidelines on extension matters

are laid down by the Extension Division, the Directorate of Extension, a subordinate office under Department of Agriculture Cooperation and Farmers Welfare provides requisite technical and managerial support in ensuring effective implementation of all Extension initiatives across all States/UTs of the Country through its following functional areas each governed by a separate Unit/Cell.

2.D.5.4 Indian Council of Agricultural Research (ICAR): KVK, is an integral part of the National Agricultural Research System (NARS), aims at assessment of location specific technology modules in agriculture and allied enterprises, through technology assessment, refinement and demonstrations. KVKs have been functioning as Knowledge and Resource Centre of agricultural technology supporting initiatives of public, private and voluntary sector for improving the agricultural economy of the district and are linking the NARS with extension system and farmers. The institute is 100 % financed by ICAR with its presence at each district level. State Agricultural Universities, ICAR institutes, related Government Departments and Non-Government Organizations (NGOs) working in Agriculture are working as implementation agencies

The major mandate of KVK is as follows;

a) On-farm testing to assess the location specificity of agricultural technologies under various farming systems.
b) Frontline demonstrations to establish production potential of technologies on the farmers' fields.
c) Capacity development of farmers and extension personnel to update their knowledge and skills on modern agricultural technologies.
d) To work as Knowledge and Resource Centre of agricultural technologies for supporting initiatives of public, private and voluntary sector in improving the agricultural economy of the district.
e) Provide farm advisories using ICT and other media means on varied subjects of interest to farmers

In addition, KVKs produce quality technological products (seed, planting material, bio-agents, and livestock) and make it available to farmers, organize frontline extension activities, identify and document selected farm innovations and converge with ongoing schemes and programs within the mandate of KVK.

2.D.5.5 National Dairy Development Board (NDDB): NDDB works with milk producers' co-operatives, private dairies entrepreneurs and consumers. It also Endeavour's to-ordinate NGOs and social and voluntary organizations related to the dairy sector. NDDB provides consulting services to milk producers' co-operative societies and private dairies. It is also involved in developing and upgrading the knowledge and skills of stakeholders through various types of practical training, workshop/seminar, extension and research activities (nddb.gov.np).

2.D.5.6 Extension Education Institutes (EEIs): EEI with the 100 % financial and technical sponsorship of central government through the Directorate of Extension, GOI, 4 EEIs are

in position at Hyderabad, Anand, Nilokheri and Jorhat. These institutes cater to the training needs of the trainers; besides, research and extension work in their respective areas of operation. As such, their activity profile as also the mandate does not reflect any direct and significant bearing for livestock development.

2.D.5.7 Agricultural Technology Management Agency (ATMA): ATMA is a society of key stakeholders involved in agricultural activities for sustainable agricultural development in the district. It is a focal point for integrating Research and Extension activities and decentralizing day to day management of the public Agricultural Technology System (ATS). It is a registered society responsible for technology dissemination at the district level. As a society, it would be able to receive and expend project funds, entering into contracts and agreements and maintaining revolving accounts that can be used to collect fees and thereby recovering operating cost. It started with the World Bank funding initially in selected districts of 7 states, since the ATMA is being seen as a major instrument to revitalize agricultural extension system in India.

In the 11th Plan document, the sub-group on Livestock Technology Transfer Service too has stressed the role of ATMA in improving the livestock sector performance. Public sector services are not the preferred option for accessing information on modern technologies in livestock production (Chander and Rathod, 2015), so an effective extension machinery and access to inputs can improve productivity by adopting latest technologies which can be provided by private extension services.

2.D.5.8 Private Extension Services: Private Extension Service is defined as the services rendered in the area of veterinary, agriculture and allied sectors by extension personnel working in private agencies or organizations for which farmers are expected to pay a fee and it can be viewed as supplementary or alternative to public extension services (Gowda et al., 1999).

Emergence of Contract Farming and Resulting Privatization Encouraging private investment and provision of foreign direct investment up to 51 % has resulted in entry of private players in poultry and dairy sectors. In poultry a high degree of privatization started from supply of day-old chick to procurement of marketable broiler and selling to final consumer i.e., from hatchery to dinning concept.

Private dairies have been established over dairy cooperatives for ex. nestle, smith line, Cavin care, ABT, Hindustan lever, Heritage, etc. these corporate houses operate with farming community through a contract agreement in which they provide variety of input services to like breeding, feed, treatment and disease prevention to the farmers and farmers provide them with their final product according to given recommendation.

2.D.5.9 NGOs in Livestock Services:

Bhartiya Agro-industries Foundation (BAIF): It was started basically to provide cattle breeding services in area where government was unable to reach out with support of government and external aid. Later on, during the course of privatization and restructuring the animal husbandry department started to face shortage of staff. This

again curtailed the services from the department. This paved way for the entry of BAIF in wider area. Currently BAIF operates in 8 states. It follows a complete recovery model called self-sustainable model. The farmers have started paying 100 to 150 rupees per A.I.

J.K. Trust Gram Vikas Yojana: It also started to invest in cattle breeding services; their mode of operation is different from BAIF because they collect money both from the farmers and government.

2.D.6 CONSTRAINTS IN ADOPTION OF EXTENSION SERVICES

There is lack of a livestock extension policy and dedicated administrative structure for livestock extension at center and state level-leading to unorganized, sporadic and ineffective delivery of extension services to livestock farmers. The focus of the State Department of Animal Husbandry (SDAH) is on healthcare and breeding aspects of livestock than production. Further the Livestock extension services in India are characterized by five biases that result in neglecting poor rural livestock-keepers, viz., top-down 'transfer of technology' approach; more focus on cattle and buffaloes, excluding other species; primary focus on milk production, neglecting other roles of livestock; concentration of services in high potential areas and; livestock extension is generally provided by men for men, despite key roles that women play in livestock farming.

There is also a lack of institutional shift from extension to entrepreneurship in livestock extension activities (Ramkumar, 2014). There is also need to move from Conventional dairy extension (with focus on improving production) vis-à-vis Commercial dairy extension (with focus on marketing, market rates, value addition, project formulation, licensing, climate change, pollution control, budgeting, sources of funds, insurance, mechanization etc.).

In view of the above challenges, livestock extension professionals need to have or acquire core competencies in extension as well as technical subject matter for effective service delivery. Moreover, the shortage in the number of Veterinary Assistant Surgeons (VASs), who are the middle level livestock extension professionals (Sasidhar P.V.K. and Murari Suvedi , 2016) and inadequate competencies among these extension professionals lead to further deterioration of livestock extension service delivery.

Poor participation of private sector and inadequate budget for livestock extension activities resulted in a weak extension component. The SDAH-as the major stakeholders for delivery of extension services spend only 1-3 % of their budget on extension activities. (Chander M. et al, 2010).

The MANAGE has conducted research on constraints in adoption of extension services in SDAH in four states, it was found that, lack of technical staff and irregular recruitment of officers. Apart from the lack of man power, lack of preparation of action plan, lack of trained staff in extension management, lack of importance given to develop knowledge and skills of the Agri-allied sector farmers, lack of extension services to

change the attitude of farmers towards newer technologies were the major constraints identified by the Agri-allied sector department staff.

2.D.7 STRATEGY FOR REVAMPING ANIMAL HUSBANDRY EXTENSION

2.D.7.1 Institutional role

a. A separate Extension Wing/ Extension Directorate to be established in all the State Departments of Animal Husbandry (SDAH) to implement extension programs and projects.
b. The central and state governments must give more importance to budget allocation and human resources. The governments may allocate 10% of the planned animal husbandry budget to extension activities. In this context, Gujarat SDAH multi-dimensional extension model (in box) with sufficient budgetary allocation may be followed by other SDAH.
c. Distance Education Centers may be established by veterinary and animal science educational and research institutes to train rural youth, to take up animal husbandry related input and advisory services in the livestock sector.
d. Veterinary and animal science educational and research institutes should focus their research on farmers needs and provide feasible solutions through technologies and pilot testing and refining of technology before releasing to end users.
e. Representation and participation of veterinarians in the grass root level extension system such as KVKs and ATMA needs to be assured/ensured.

2.D.7.2 Orientation of extension approach

a. Provision of extension advisory along with input services at door step and public involvement will certainly improve the number of farmers availing the advisory services.
b. Emphasis may be given on community-based extension approach on the similar lines of community health workers in the medical field.
c. Extension should be made a compulsory part of subsidy schemes and should be through group/cluster approach.
d. The focus of SDAH must shift gradually from clinical and reproduction-oriented services to preventive medicine, production, market-oriented approaches and entrepreneurship development.
e. Extension efforts need to be oriented towards small ruminants (Sheep & Goats) along with other livestock.

2. D.7.3 Infrastructure

a. Quality inputs and infrastructure like training hall, hostels, mobile vehicles and printing press with relevant audio-visual facilities for information delivery are major elements and should be addressed with focus on certain issues relating to what farmers' want, demand and supply, low input and high output with special emphasis on technology solutions.

2.D.7.4 Farmer empowerment

a. There is a need to improve the decision-making capacity of farmers through networking and coordination of all service agencies, and shift from subsidized services to quality services.
b. Successful farmers may be recognized and included in farmer-to-farmer network for transfer of recommended practices.
c. Promotion of farmers' associations in the livestock sector such as Progressive Dairy Farmers Association, Small Ruminant Farmers' Association, Poultry Farmers' Association, Pig Farmers Association, Dairy Cattle Breeders Association, Buffalo Breeders Association, Sheep and Goat Breeders Association, Poultry Breeders Association etc. will facilitate community extension and farmer to farmer extension.

2.D.7.5 Strengthening of institutional linkages

a. The Extension wing of SDAH may be linked with veterinary and animal science academic and research institutions at regional level along with ATMA, KVK and NGOs working in the area to transfer region specific latest technology effectively and efficiently.
b. Veterinary universities and research institutions are constrained by lack of human resources, budgets and infrastructure. The potential of private extension service providers needs to be explored in Public Private Partnership (PPP) mode to take research results to the end users. CSR funds of different organizations/agencies may also be tapped for such extension activities.
c. In view of poor/weak linkages between the veterinary universities, national research institutions/centers (working in veterinary and animal science sector) and the farmers, the extension mechanism needs to be strengthened along with focus on building a farmer friendly extension system. Necessary financial arrangements, infrastructure and human resources may be ensured for its effectiveness.

2.D.7.6 Human resource development/ management

a. Emphasis on quality education: Approaches, strategies and curriculum need to be developed with proper balance of knowledge and skills, which can meet all the social, managerial and technical competencies and revision may be carried out at regular intervals as per the requirement. There may be more emphasis on hands on training to UG students in the villages, for improving extension and communication skills.
b. Veterinary Officer/Veterinary Assistant Surgeon/Livestock Development Officer may be placed at district level to help and guide extension work in the district.
c. All the input services for livestock farming such as concentrate feed, mineral mixture, semen doses, A.I. skills pharmaceutical drugs, vaccines, utensils, equipment, insurance services etc. at block level may be brought under the control of the veterinary officer, who will monitor and regularize such services in his jurisdiction (block level) to avoid indiscriminate use and thereby further loss to the farmers.
d. Focus may be on Capacity building of extension functionaries through various types of need-based training programs at regular intervals. In this context, this may be

initiated through selection and nurturing of a few selected professionals towards extension.

e. The performance of extension functionaries in SDAH may be evaluated on the basis of the number of farmers initiating/continuing livestock farming in their jurisdiction, which may be directly correlated to his/her promotion and career advancement scheme to boost work efficiency. The services of veterinarians may be graded and they may be rewarded/ recognized for encouragement.
f. Continuing veterinary education program may be made mandatory for the Veterinary Officer/Veterinary Assistant Surgeon/Livestock Development Officer and can also linked with their promotion and career advancement scheme.

2.D.7.7 Gender mainstreaming

a. Since there is a strong informal association of rural women with livestock, it is necessary to create a matching program and budgeting for women so that their participation gets institutionalized or else they will continue to remain invisible workers. It would be more effective, if women Extension workers disseminate the technologies to the women farmers both in formal and informal mode.

2.D.7.8 Use of Information and Communication Technology (ICT)

a. There may be more focus on "e-extension, m-extension, social media and market led extension" etc. along with use of latest technologies like online database of farmers, geo tagging, online portals, mobile apps etc. In this context, the Centre and State governments should ensure necessary infrastructure and capacity building.

2.D.8 LET'S SUM UP

The role of the livestock sector has not remained confined to household nutritional security and employment generation alone, but it is becoming a major economic activity to support the other needs of a farm family. The continuous growth of this sector is reflected through its increasing contribution to the agriculture sector GDP year after year. Presently this sector contributes nearly 29 % to the total agriculture sector GDP.

According to the Central Statistics Office (CSO), for the first time, the value of milk produced has exceeded the total value of food grains (cereals plus pulses) in 2016-17. Moreover, the livestock sector is being viewed as a major engine for doubling farmers' income by 2022.However, the potential of this sector for doubling farmer's income, still remains untapped due to several reasons. In most of states, veterinarians who are working in the State Department of Animal Husbandry (SDAH) at grass-root level, are designated as Veterinary Officers and Veterinary Assistant Surgeons and mainly focusing on delivery of clinical and reproduction-oriented services to livestock farmers. In fact, these officers have a very broad mandate of livestock sector development of which livestock extension is an inevitable part but it remains neglected.

To address the above challenges in livestock extension service delivery, the 10th and 11th Planning Commission recommended that, either the SDAH should create a separate wing within the department for livestock extension service delivery (Model-I) or some of the veterinary officers of SDAH may be deputed and designated exclusively for livestock extension services (Model-II). Accordingly, only a few SDAH (7-8) came forward and created a separate wing at various levels i.e., SDAH headquarters, Division, District and Block etc. and made some efforts to improve the livestock extension component. However, a majority of the SDAH have deputed only a few officers either at SDAH headquarter level or Divisional level, District or Block level and designated as Veterinary Officer-Extension, Veterinary Assistant Surgeon-Extension, where, for delivery of livestock extension services, these designated officers have to depend on other officers, who are mainly looking after animal health and reproduction services for livestock farmers. Therefore, this particular arrangement has not served the purpose and livestock extension has remained weak and neglected.

In order to tap the potential of the livestock sector, the focus of SDAH needs to shift gradually from clinical medicine and reproduction-oriented services to preventive medicine, production, market-oriented approaches and entrepreneurship development, which is possible through strengthening of the extension component in the livestock sector. Moreover, this will ensure sustainability of the livestock sector.

2.D.9 CHECK YOUR PROGRESS

1. Why there is need for a specialized livestock extension service?
2. What are issues of extension services in livestock sector?
3. State the major institutions which involve in livestock extension delivery?
4. What are the major constraints in adoption of extension services?
5. State the strategy for revamping animal husbandry extension?

2.D.10 FURTHER READINGS/ REFERENCES

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UNIT 3: SUSTAINABLE FISHERIES DEVELOPMENT
A. MANAGEMENT OF INLAND AND MARINE FISHERIES

Highlights of the Unit

- Objectives
- Introduction
- Roles and status of marine and freshwater aquaculture in India
- Major challenges and issues marine and freshwater aquaculture in India
- Let's sum up
- Check Your Progress
- Further readings/references

3. A.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Status of Indian fisheries
- Status of marine and freshwater aquaculture in India
- Status of brackish water aquaculture in India
- Shrimp farming
- Issues in Indian aquaculture
- Climate resilient aquaculture
- Technological and developmental initiatives in fisheries
- Issues in marine fisheries management
- Sustainable marine fisheries development

3.A.1 INTRODUCTION

Fisheries play an important role as food in the world, directly accounting for about 20% of the animal protein consumed by humans and indirectly supporting food production by aquaculture and livestock industries. Indian fisheries now occupy the second position in global fish production with an annual growth rate of 4.7%, with 3.2% growth in marine fisheries and 6.2% growth in inland sector, thereby contributing 1.1% of the total GDP and 5.3% of the agricultural GDP of the nation. As per the Indian Livestock Census, 2003, 14.49 million people were engaged in various fisheries related activities at primary level and almost the twice number along the value chain.

3.A.2 PRODUCTION

Global fish production was 171 million tons in 2016, with aquaculture representing 47% of the total. During 2017-18, the total Indian fish production was 126.10 lakh tons consisting of 26.93 lakh tons from Marine sector (29.29%) and 89.17 lakh tons from Inland sector (70.71%). The details of Indian fish production during last 6 years are as follows:

Year	Fish Production (lakh tons)		
	Inland	Marine	Total
2012-13	57.19	33.20	90.40
2013-14	61.36	34.43	95.79
2014-15	65.77	34.91	100.69
2015-16	72.10	35.80	107.90
2016-17	77.69	36.41	114.10
2017-18	89.17	36.93	126.10

The total first sale value of fisheries and aquaculture production in the country during 2016-17 was estimated at Rs 1,12,330 crores, of which Rs 65,760 crores were from inland and Rs. 46570 crores from marine sector.

3.A.3 INLAND FISHERIES

Inland fishery resources: India has an abundant inland fisheries resources providing ample scope for development of fisheries and aquaculture. The Inland fisheries resources are mainly composed of), Ponds / tanks (24.14 lakh ha), brackish water area (12.40 lakh ha) and saline & alkaline affected area (12.00 lakh ha) Rivers and Canals (1.95 lakh KM length), Reservoirs (35.4 lakh ha water spread area Flood plain / derelict water bodies (7.98 lakh ha). These resources include 8253 km long rivers and 41600 ha of reservoirs in the hilly and cold areas providing suitable environment for culture of cold-water fishes like trout.

Technological innovations and developmental initiatives in inland fisheries: Fish seed production is fundamental for the expansion and development of freshwater aquaculture. In India, carps constitute approximately 80 per cent of total aquaculture production. The carp hatcheries are the primary means of the production of seed. It is estimated that India had produced 36,566 million fry in 2011-12 (DAHDF, 2013) and that there are more than 420 carp hatcheries in India (Basavaraja, 2007) which accounts for 95 per cent of seed source. Since 1976 many enterprising fish farmers have ventured into carp breeding on a commercial scale by successfully adopting induced breeding and hatchery technologies (Jhingran, 1991). The hypophysation technique developed in 1957 laid the foundation of the technology and thereafter, a steady progress towards refinement of the technique has been registered, which has revolutionized carp seed production in the Indian subcontinent (Routray *et al.,* 2007). These technological evolutions along with the entrepreneurship of farmers enabled the country to achieve remarkable growth of the fish seed sector over the last three decades.

The ICAR research Institutes, fisheries colleges under the State Agricultural Universities, private and other R & D institutes have developed various technologies for enhancing the

fish production in the country. Some of the important technologies are listed below.

Breeding and Seed Rearing for Indian major carps: In 1957 induced breeding technologies were developed for Indian Major Carps (Catla, Rohu and Mrigal), and this provided the impetus for carp culture in the country. Further, the rearing of carp seeds was also standardized. Adopting the induced breeding technology, breeding of many native fish species has also been evolved in the hatchery system.

Composite Fish Culture: Evolution of composite fish culture using multiple fish species in the same pond by Central Inland Fisheries and Research Institute (CIFRI) has paved way for scientific fish culture in the country.

Integrated Fish Farming: The integration of fish farming with pigs, ducks, poultry, cattle and various agriculture and horticulture practices resulted in better utilization of resources.

Rice cum Fish Culture: Growing the fish in the paddy fields is widely practiced in Asian countries and north eastern and eastern states in India. *Ziro Valley* in Arunachal is famous for rice fish cultivation since long time. The rice cum fish cultures mainly for sustenance.

Stocking Advance Fingerlings in Reservoirs: National Fisheries Development Board (NFDB), Hyderabad with the technical support of ICAR-CIFRI took the initiative to enhance the productivity of reservoirs by stocking advanced fingerlings @ 500 /ha in large reservoirs, 1000/ha in medium reservoirs and 2000 /ha in small reservoirs. CIFRI has reported increased productivity in all the stocked reservoirs. But the challenge is the sustainable development these reservoirs and arranging for supply of advanced fingerlings through localized (*in situ*) fish seed rearing involving stakeholders.

Integrated development of Reservoirs: Under the Integrated Development of reservoir fishery, activities related to pre-culture preparation, de-weeding, establishment of hatcheries, fish rearing units, fish seed stocking, cage culture, feed mills, boats and nets, landing centers, cold storages, ice plants and fish transport facilities are assisted under Blue Revolution Scheme of Department of Animal Husbandry, Dairying & Fisheries (DADF), Government of India. The objective is to support sustainable management of reservoir fishery involving stakeholders.

National Mission for Protein Supplements (NMPS): The DADF, GOI had launched NMPS scheme during 2011-12 with 100% assistance to adopt new technologies to initiate cage culture in open sea, cage culture in open water bodies, fish seed rearing in pens etc. Further, the assistance was provided for expansion of aquaculture are and for creation of post-harvest infrastructure facilities. This resulted in large scale cage culture in reservoirs and other open bodies across the country with a production up to 5 ton per cage (96 m^3 size) of Pangasius. Similarly, open sea cage culture was demonstrated at selected sites along the coast using fish species like cobia, sea bass etc. This demonstration has led to expansion of cage culture in many reservoirs of the country for culture of pangasius and tilapia.

3.A.4 MANAGEMENT INITIATIVES

a. **Fish Farmers Development Agency (FFDA):** The FFDAs were started in the year 1974-75 to popularize freshwater aquaculture in small ponds and tanks. The fish farmers were assisted by providing tank on long lease, subsidy on inputs like fish seed, fish feed, fishing nets etc. and on marketing infrastructure. Totally 429 FFDAs established in the country, had developed about 8.32 lakh ha of pond area through about 14.22 lakh beneficiaries. Similarly, 39 brackish water FDAs (BFDAs) established in 10 coastal states for development of brackish water aquaculture had covered about 0.43 lakh ha brackish water area through about 0.35 lakh beneficiaries. The productivity from small ponds and tanks reached a level of 2.5 to 3.0 ton /ha /year. However, FFDAs and BFDAs have been discontinued in many states.
b. **Leasing Policy:** Most of the inland resources are common properties (though fish farmers own their ponds) used for multiple purposes. With establishment of FFDAs the policy of long lease of water bodies was started. This has resulted in all the states developing policies for long term lease, not uniformly as every state has its own mechanism (3 -10 years) of tanks, ponds, lakes, reservoirs and rivers facilitating in planning and fisheries development in these water bodies. A few states have developed policy for leasing reservoirs for large scale cage culture without effecting the livelihood of local fishermen.
c. **Rastriya Krishi Vikas Yojana (RKVY):** RKVY scheme was initiated in 2007 as an umbrella scheme for ensuring holistic development of agriculture and allied sectors by allowing states to choose their own development activities. Under RKVY, States have been provided flexibility and autonomy for selection, planning approval and execution of projects/ programs as per their need, priorities and agro-climate requirements. All the states have given emphasis to enhance the fish production and to assist the fish farmers in adopting recent technologies.

3.A.5 STATUS OF FRESHWATER AQUACULTURE IN INDIA

The culture systems adopted by farmer vary greatly depending on the input availability and investment capabilities of the farmer. Based on the levels of inputs and outputs the culture systems can be categorized as low, medium and high input systems.

a. **Low-input system:** The natural productivity of the pond is increased by using low-organic and inorganic fertilizers, without any supplementary feeding. The fish production of around 2 - 3 tones/ha/year.
b. **Medium-input system:** This system includes proper pond preparation, ideal fish seed stocking density, periodic fertilization and regular feeding with oil-cake-bran mixture (protein 25-27 %) coupled with water quality and fish health monitoring. Composite culture of Indian Major carps (Catla, Rohu, Mrigal) with three Exotic Carps (Grass carp, silver carp and common carps) are practiced, with production levels of around 6-8 tones/ha/year.

c. **High-input system:** High fish seed stocking density combined with balanced feed are the characteristics of intensive culture system aimed at higher fish production from unit area. In some cases, intensive aeration and water replenishment are also adopted. A production level of about 12-15 tons ha^{-1} yr^{-1} of carps and 25 to 40 tons ha^{-1} yr^{-1} of Pangasius has been achieved by farmers in the states of Andhra Pradesh, Chhattisgarh and from other states etc. However, there exists a high yield gap in aquaculture in different states of India.

3.A.5.1 Carp culture: Indian freshwater aquaculture system mainly revolves around 3-6 species of carps. Traditionally fish culture began in smaller water bodies as polyculture of Indian major carps collected from the rivers during breeding season. Introduction of Asiatic carps namely Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmicthys molitrix*) and Common carp (*Cyprinus carpio*) in composite fish culture has resulted in enhancing the productivity. The national average production from community ponds and tanks has increased from about 600 kg $ha^{-1}yr^{-1}$ in 1970s to over 2.9 tons/ha/year in 2015. In individually owned ponds, farmers are obtaining production levels of 8 – 15 tons of carp /ha /year. Farmers have obtained better production through stocking of advanced fingerlings, stunted fingerlings, yearlings, and 'zero' size seeds (about 200 – 250 g). Farmers have introduced many innovations such as feeding through suspended bags, seed stocking in batches and harvesting in batches (Multiple stocking and multiple harvesting), altering stocking ratio based on market demand, culture of only Rohu (85 - 90%) and Catla (10-15%) in Andhra Pradesh, poly culture of fresh water giant prawn with Catla etc.

3.A.5.2 Pangasius culture: Pangasius fish initially entered India as an aquarium fish, has flourished as an important species for culture in fresh water (as food fish). Government of India officially allowed the culture of Pangasius in 2010. Farmers have realized a production of 10 to 40 tons ha^{-1} under locally improved culture practices. Floating feeds and scientific management practices are used during culture. The commercial scale Pangasius seed production and rearing has been recently started by only a few hatcheries, mainly in West Bengal.

3.A.5.3 Tilapia culture: GIFT tilapia (*Oreochromis niloticus*) is an important species of culture having a faster growth rate and world-wide market demand. Another species of tilapia (*Oreochromis mossambica*) was accidently introduced in 1950s to India, and it has spread across the country due to its prolific breeding and adaptability to wide range of environmental condition. Overpopulation of tilapia has affected the fisheries of several reservoirs and lakes.

Government of India has permitted selected hatcheries to produce fish seeds of tilapia (Mono sex and mono culture of Nile /GIFT / golden tilapia). Many farmers are cultivating GIFT tilapia have yielded with better results. Tilapia is a good species for culture in cages and under Re Circulatory Aqauculture System (RAS). The extent of

culture, production systems, optimum feeding regime, quality of seed (% of male seed), and bio-security measures adopted, and marketing issues have to studied in detail to assess the commercial success and to develop required post-harvest infrastructure for marketing in both domestic and international markets.

3.A.5.4 Pacu: Pacu, *Piaractus Brachypomus* has illegally entered India during early 2000s from neighboring countries and commonly known as 'Pirapitinga' and 'Roopchand'. It is mostly cultivated in many states in combination with Indian major carps with a production yield of 12-15 tons/ha. There is a good demand of pacu in the market.

3.A.5.5 Small indigenous species: Small indigenous freshwater fish species (SIF) may be defined as fishes which grow to the size of 25-35 mm at maturity. Rural communities depend highly on these indigenous species of fish for nutrition. It has been reported that some species such as mola (*Amblypharyngodon mola*), contain high amount of vitamin A along with micronutrients and minerals. World Fish Centre, Malaysia has partnered with Government of Odisha to provide technical support for the culture of SIF. The localized culture and consumption of SIF has a major role in addressing nutritional bio-security in the rural India.

3.A.5.6 Freshwater prawn: Culture of high value prawn species like Scampi, *Macrobrachium rosenbergii* and *M. malcolmsonii* was in vogue, especially in Andhra Pradesh. Later, due to poor quality of seed and disease outbreak, scampi culture was completely abandoned. Now, the farmers in coastal states prefers brackish water species (*L. Vannamei*) due to high yield and better income. However, many farmers in Andhra Pradesh, Telangana, Maharashtra and Gujarat collect wild seeds of fresh water prawn and stock in reservoirs and major tanks. This practice is giving fairly good production and income. Further, ICAR-CIFA, Bhubaneswar has developed genetically improved scampi which is awaiting large scale seed production and culture. The farmers have also incorporated prawn in the composite fish culture (Catla, Rohu and Mrigal) "Polyculture". This practice is also widely followed in many states of India.

3.A.5.7 Trout farming: Culture of rainbow trout at high altitudes of Himachal Pradesh, Sikkim, Uttaranchal, Jammu & Kashmir and Arunachal Pradesh having low water temperature has increased rapidly. Government of India has funded establishment of hatcheries, raceways and feed mills to facilitate trout production in these states.

3.A.5.8 Culture of other species: Many other species of local fishes like magur (*Clarias sp*), singhi (*heteropneustes sp*), pabda (Ompak sp) etc are cultured by small farmers, especially in Eastern India including NE states. In addition to those minor carps is also been cultured in mnay parts of India Puntius gonionotus and others species. These minor carps have also been incorporated in composite fish culture system.

3.A.6 BRACKISH WATER AQUACULTURE IN INDIA

India is blessed with an area of about 1.2 million ha brackish water area suitable for aquaculture. Presently, brackish water aquaculture in our country is synonymous with shrimp farming.

3.A.6.1 Traditional shrimp farming: Traditional brackish water culture system in *bheries* (manmade impoundments in coastal wetlands) of West Bengal and *pokkali* (salt resistant deep-water paddy fields) along the Kerala coast involves impoundment of tidal waters along with fish and shrimp seeds. Harvesting of marketable sized fish and shrimp is done regularly during spring tides through traps placed near the sluice gates. There is no manuring or feeding, and these systems have been sustaining production levels between 500-750 $kg^{-1}ha^{-1}year^{-1}$ with shrimp contributing 20-25 % the total production.

3.A.6.2 Modern shrimp farming: The modern shrimp farming in the country was initiated in early 1990s with tiger prawn (*Penaeus monodon)* farming. Large-scale development of shrimp farming started with the establishment of the commercial shrimp hatcheries. A production of 4-6 tons/ha of tiger prawn was obtained under semi-intensive culture system. The production increased to about 82500 tons in 1994-1995. Later owing mainly to outbreak of white spot syndrome, tiger prawn culture got reduced drastically. However, introduction of exotic species *Leptopenaeus vannamei* (White leg shrimp) revived the brackish water shrimp culture. Coastal Aquaculture Authority (CAA) Chennai, under Government of India agency, is authorized for granting permission to import Specific pathogen free (SPF) *vannamei* brood stock and for giving permissions for *vannamei* culture by farmers. Vannamei is cultured under intensive system with a production of 8-10 ton per ha per crop.
Among fin fishes, technologies for breeding and seed rearing have been developed for Sea bass, silver pompano etc. High export prices of crabs have made fattening of species like *Scylla serrata* and *Scylla tranquebarica* a remunerative farming practice. In addition, certain brackish water fish species as milkfish (*Chanos chanos*), pearl spot (*Etroplus suratensis*) and mullets (*Mugil* spp.) have shown promises for commercial aquaculture in inland saline soil / water areas.

3.A.7. ISSUES IN INDIAN AQUACULTURE

3.A.7.1 Productivity enhancement: Increase in productivity is intrinsically linked with increased use of quality inputs like fast growing genetically improved fish seed, quality fish feed and adoption of recent technologies. While intensification of the aquaculture practice could trigger environmental concern, practice of responsible aquaculture, best management practice and HACCP are some of the themes stressed upon in recent years in the freshwater aquaculture sector.

3.A.7.2 Species and system diversification: Freshwater aquaculture in India is mainly carp based. The carps together contribute to about nearly 80% of total aquaculture production in India. Some native species also offer scope for diversifying their culture

system into more rewarding farming systems. Flexibility with regard to species and input use for utilizing these resources effectively for fish culture as per the regional requirement would lead to effective utilization of the seasonal ponds for increasing fish production. Integrated farming with livestock and/or agri-horticultural components and cage culture and pen culture may be promoted in open waters for culture-based capture fisheries to increase the productivity of the open waters.

3.A.7.3 Feed based aquaculture: Globally the feed-based aquaculture constitutes about 75% of the current production, but in India it is less than 30%. This indicates the scope for increasing the feed-based fish culture in India. It is also necessary to convert 10- 15% of the aqua farms of the country to intensive aquaculture systems such as raceway culture, running water culture, re-circulatory aquaculture etc. which are complete feed-based aquaculture systems. As the feed constitutes more than 60% of the production cost and efficiency in the feed use has a strong bearing on the cost-benefit ratio of the aquaculture operation. The use of pelleted feed for carp farming was almost negligible. The sustenance and further expansion of the aquaculture activity needs production have feed by using locally available ingredients" Farm made feeds". Research institutes have mapped out locally available resources that can be used for fish feed preparation.

3.A.7.4 Genetic up-gradation and quality seed production: ICAR- Central Institute for Freshwater Aquaculture (CIFA), Bhubaneswar is continuously improving genetic quality of Rohu and has produced genetically improved (GI) 'Jayanthi Rohu', which has shown nearly 17% faster growth rate than conventional Rohu. Similarly, early results of improved Catla of ICAR-CIFA has shown great promise. Genetically improved scampi seeds have been developed by ICAR-CIFA, awaiting large scale introduction. The state fisheries departments have to develop an action plan to propagate GI and quality seed through Government and private hatcheries. Further, registration of fish seed farms and fish seed certification will immensely help the sector. Multiple breeding and offseason breeding through controlled gonad maturation in carps are important innovations for farmers. The feed developed by ICAR-CIFA for carp brood stock "CIFABROOD" has the potential for fishes getting early maturation, early breeding and possessing a feature of producing quality seeds.

3.A.7.5 Bio-safety and bio-security: Appropriate guidelines for laboratories, containment, field trials and risk assessment are highly essential. An equally challenging concern is biosecurity, a system of cumulative steps for the prevention, control and eradication of infectious diseases to protect the farm stock, requires to be stringently implemented from the hatchery to the grow-out stage.

3.A.7.6 Biodiversity loss and ecosystem deterioration: Conventional expansion and intensification will have severe impact on ecosystem and biodiversity. In coming decades uncontrolled activities could lead to the loss of up to 11% of the world's natural areas, once biodiversity reduces, ultimately genetic diversity within a particular species will be reduced.

3.A.7.7 Cluster-based aquaculture: Even though a large proportion of global aquaculture production currently comes from small scale farmers, they face major challenges to remain competitive and participate in modern value chains. Increasing demand for higher value internationally traded export species such as shrimp has led to more integrated production - distribution chains and coordinated exchange between aquaculture farmers, processors and retailers. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture is still to be adopted in the country. However, Government of India is emphasizing for the selection of beneficiaries in clusters for effective management of culture operations. Though the practice of cluster approach of development is prevalent in agriculture, the same has not been with aquaculture in India.

3.A.7.8 Farmers' Producers Organizations (FPO): Farmers' Producers Organization (FPO) is defined as a formal voluntary membership organization created for the economic benefit of farmers to provide them with services that support their farming activities such as bargaining with customers; collecting market information; accessing inputs, services and credit; providing technical assistance; and processing and marketing farm products. Small Farmers Agri Business Consortium (SFAC) has been set up to oversee of Farmers Producer Organization. SFAC will act as a lead project promoter on behalf of State Governments and will undertake all the necessary interventions to achieve the deliverables under this project. On all critical matters, such as choice of districts and clusters, identification of crops and commodities for focused development SFAC will work in coordination with Central, State and District level officials of the concerned departments. In the fishery sector activities identified are input supply, production services, commercial fish culture, ornamental fish production, financial services, training and advocacy. However, FPOs in various commodities have been initiated and successfully run, FPOs in fish is still at the primitive stage. But there is a wide scope for expansion of FPOs in this sector.

3.A.7.9 Health management and disease surveillance: Increased occurrence of pathogens comes as a sequel to the intensification process aquaculture activity. The misuse and drawbacks in antibiotics, problems of emerging pathogens, trans boundary diseases, poor quarantine etc are further adding up to these issues for moving into better health management practices. The production of SPF stocks for important viral diseases of prawn might be a need in future in case of re-emergence of the pathogens. Targeted active surveillance and health management practices need to be taken up to prevent those diseases through development of molecular diagnostics and vaccines.

3.A.7.10 Climate resilient aquaculture: Global warming is likely to create favorable conditions for the growth of causative organisms and rise in the responses of disease occurrences spread by vectors. Similarly, alterations in other sensitive water quality parameters such as ammonia, dissolved oxygen and water temperature may have

pronounced effect on feed utilization efficiency, growth and even on the sensory qualities of the cultured fish species. Use of large quantity of manure, fertilizer, feed, therapeutics and other inputs, aimed at increasing the fish production, has made the modern fish farming system more energy intensive. In this context, the vast coverage of aquaculture ponds could be a significant source of greenhouse gas emission. However, responsible aquaculture practice can alter the trend by making aquaculture a pro-carbon sink process rather than contributing to the global greenhouse gas emission. Research institutes have been working on developing package of practices on technologies that can combat climate change. Above all the future of aquaculture is with expected scarcity of water.

3.A.7.11 Private investment and public-private-partnership: Fish farming is a capital-intensive activity and needs an initial heavy investment for renovation or construction of the culture system, for seed, feed, fertilizers and management during the culture operations. There are opportunities to invest in establishment of hatchery, seed production; domestic fish marketing and fish processing. For aquaculture development, a strong system of public private partnership needs to be developed where the private sector, industry, farmers, communities, government, research institute, civil societies work together. Establishment of aqua parks, mega hatcheries, processing units etc. can be done under PPP.

3.A.7.12 Community participation in aquaculture: In rural India, major water resources are owned by village communities and the revenue or water resource departments. The water resources are neither leased to farmers nor utilized by the concerned department because of multiple reasons. In community-based aquaculture, common interest groups work together by sharing equal responsibilities. Utilizing such water bodies would provide self-employment to the rural poor in their villages. It is estimated that in a state like Odisha more than 60% of the water resources are common property. These resources are not used to the extent it can be used. Government policies on using these resources effectively can augment fish production. In simple terms the practice is called Community Aquaculture. Community-based aquaculture founded on the principles of common interest groups working together regardless of sex and age has been an effective tool for implementing scientific aquaculture programs in India. Water bodies that do not interest villagers are targeted for use to avoid communal problems.

3.A.8 MARINE FISHERIES

India has 8118 km long coastline and 2.02 million sq. km area of Exclusive Economic Zone (EEZ) including 0.5 million sq. km area of continental shelf with an estimated fisheries potential of 44.12 lakh tons. The marine fisheries have gained importance in the country for its significant contribution to food and nutritional security, employment generation and foreign exchange earnings. The average marine fish catch during the last 6 years (2012-13 to 2017-18) was around 35.28lakh tons. The sector involves a large human resource base with nearly 4.06 million fisher folk comprising one million active fishermen. Among the active fishermen, 33 per cent are employed in the mechanized sector, 62 per cent in the motorized sector and 5 percent in the artisanal sector.

Globally, India ranks 6th position in terms of fish production with a share of about 4.5% and under the Blue revolution, the country is looking forward to enhance marine capture fish production to 43.10 lakh tons by 2020 with an anticipated enhancement of nearly 0.71 million tons (nearly 20% increase). The production is mainly contributed by Pelagic resources such as oil sardine, ribbon fish, Indian mackerel accounting for 21.28 lakh tons with a share of 48.2% to total marine fish production followed by demersal resources such as penaeid and non-penaeid shrimps, cephalopods, perches, croakers contributing 20.67 lakh tons with a share of 46.8% and the Oceanic resources mainly comprising yellow fin tuna, skip jack tuna, big eye tuna, bill fishes, pelagic sharks, barracuda, and dolphin contributing 2.17 lakh tons with 4.9% share to total marine capture fish production.

The projected marine fish production by 2050 is expected to be of 6 million tons. While the fishery resources from the near-shore waters are exploited to maximum extent, the deep sea and oceanic waters offer greater opportunities for increasing the catch. Realizing this, the GOI has proposed to support over 1230 Deep sea Fishing Vessels spread across all the 13 maritime states in the country. Of the total marine fish production, 75 per cent is being harvested from the mechanized sector, 23 per cent from the motorized sector and 2 per cent from the artisanal sector. Mechanized trawl fishery now forms the most important fishing method in the country contributing about 55 per cent to the total marine fish production.

3.A.9 TECHNOLOGICAL INNOVATIONS AND DEVELOPMENTAL INITIATIVES

During early days after Independence, marine fishes ware mainly caught using non-synthetic nets operated from shore or from small non-mechanized fishing boats. The catch was mainly consisted of pelagic fishes. However, after Independence many developmental and technological initiatives were introduced for the benefit of fishermen. Some of the important initiative are as follows:

a. Developments in craft technology - Introduction of mechanized boats (trawl and purse-seine boats) and motorized boats with mechanization of propulsion, mechanization of gear and catch handling.
b. Development of fishing harbors and fish landing centers for safe navigation and landing of mechanized and motorized fishing boats.
c. Introduction of boats built with wooden planks, Fibre Reinforced Plastic (FRP), or steel in place traditional dugout wooden canoes.
d. Introduction of synthetic gear materials
e. Capacity building in operation of mechanized fish boats, operation of trawl nets, purse-seine nets etc.
f. Developments in acoustic fish detection and satellite based remote sensing techniques
g. Advances in electronic navigation and position fixing equipment, sea safety equipment's, communication equipment's.

h. Awareness on the need for responsible fishing to ensure sustainability of the resources, protection of the biodiversity and environment safety and energy efficiency
i. Capacity building in hygienic handling of fish, preservation and storage of fish on boat.
j. Social security – Group accidental Insurance, Financial relief during closed fishing season, biometric identification cards, extending support of coastal guards and navy to ensure sea safety, Group housing programs etc.
k. Implementation of various measures for sustainable development of marine fisheries resources like motorization of traditional craft, purchase of safety kit to enhance fishermen safety at sea, artisanal fishermen for procurement of FRP boats and insulated fish and ice holding boxes, rebate on HSD for fishers, establishment of Vessel Monitoring System (VMS) etc.
l. Registration of all fishing boats operating along the coast through a common web portal (Real Craft) to monitor and to regulate the fishing efforts. Nearly 2.57 lakh fishing boats representing traditional, motorized, mechanized and deep-sea fishing boats have been registered under this portal.

3.A.10 ISSUES IN MARINE FISHERIES MANAGEMENT

Indian Marine fisheries sector has seen phenomenal growth during last 60 years. However, the sector is facing many concerns/ issues which may adversely affect the marine fisheries. The biggest concern among many are on the declining marine fisheries resources. Some of the issues are as follows:

a. Overcapacity of fishing boats especially in the near shore waters resulting in reduced fish catch and loss in fishing operations. There are no regulations to control the introduction of new fishing boats.
b. The artisanal fishermen are unable to earn their livelihood owing to exploitation of fish catch in the near shore waters by mechanized fishing boats. Although fishing zones have been introduced in some states, such regulations are not implemented to protect their interest.
c. Operation of fishing nets, which are harmful – paired trawling or bull trawling, purse-seine fishing using high power LED lights etc.
d. Coastal pollution due to untreated sewage from cities, towns and villages, and from Industries resulting in loss of fishery wealth.
e. Loss of Biodiversity – marine fish fauna is adversely affected due to various factors. The catch of some varieties of fishes is getting reduced.
f. Increasing fishing cost owing to increase in the cost of fuel and reduced profitability
g. Inadequate infrastructure facilities at fishing harbor and fish landing centers – the existing infrastructures are inadequate to meet the demand created by increased fishing boats and increased size of fishing boats (up to 24 meter in length). Further, most of the fishing harbors and landing centers are not maintained hygienically.
h. Insufficient Marketing facilities - The fish marketing system is highly ineffective and unhygienic resulting in less income to fishermen and in increased post-harvest losses.

i. Increasing Intra & Inter sectoral conflicts; conflicts between fishermen of different states, conflict in fishing near international waters and conflict between fishermen operating different kinds of nets, and conflict between traditional fishing boats and mechanized fishing boats.
j. Limited capacity in terms of infrastructure and skill to harness deep sea resources

3.A.11 SUSTAINABLE MARINE FISHERIES DEVELOPMENT

As per Integrated National Fisheries action plan 2020, Indian marine fishery sector has to implement appropriate management measures for sustainable development and also to increase the income of traditional fishermen. Many management initiatives, like adoption of closed fishing season during peak fish breeding season; regulation of illegal fishing effort through boat registration and issue of annual fishing licenses; ban of paired trawling or bull trawling; ban of purse-seine fishing using high power LED lights etc. have been enforced as a part of regulating the marine fisheries. Further, the authority to register fishing boats up to 24 m OAL has been delegated to state fisheries departments, which has resulted in introduction of bigger (up to 24 m) fishing boats capable of fishing in deeper waters. However, this has resulted in requirement of higher draught and increased wharf height in fishing harbors. The demand for ice has also increased. Hence, creation of adequate infrastructure and enhancing the fishing capability of traditional fishermen are important issues for consideration in the coming years. In addition, adoption of following measures is also important:

a. Reducing / limiting /restricting overcapacity in the mechanized sector – banning the introduction of new mechanized fishing boats, except for replacement of old boat, for certain period (say 10 years); Concurrent study of impact of such restrictions.
b. Limiting the engine horse power of mechanized boats – to avoid wastage of fuel; to avoid juvenile/ under size fishing; to prevent the damages to fish.
c. Diversification of fishing for capture of underutilized deep sea and oceanic resources.
d. Regulation of mesh size to avoid catching juvenile fishes and under size fishes.
e. Imposing restriction on fishery for certain species, size of fish caught (minimum legal size), area etc. Kerala state fisheries has introduced minimum legal size (MLS) for catching and marketing of many species with the support of fishermen and ICAR-CMFRI.
f. Promotion of marine sanctuaries, installation of artificial reefs and sea ranching
g. Effective code of conduct for responsible fishing; creating awareness.
h. Encourage mariculture by fishermen and their organization; Encourage mussel culture, bivalve culture and seaweed culture as a livelihood option for traditional fishers; Encourage culture of sea bass, *Lutjanus sp, Etroplus suratensis* etc.in small cages placed in the estuaries and back waters by fishermen using the technical expertise of ICAR-CMFRI.
i. Encourage the community adopted self-regulations like restricting fishing on festivals, avoiding night fishing, avoiding monsoon fishing etc.

3.A.12 LET'S SUM UP

Awareness creation among all stakeholders against non-sustainable fishing practices with a participatory approach has become inevitable in fisheries management. Further, the stakeholders must be involved in all management decision (co-management).

3.A.13 CHECK YOUR PROGRESS

1. State the status of Indian fishery?
2. Describe the status of marine and freshwater aquaculture in India?
3. Describe the status brackish water aquaculture in India?
4. Write about shrimp farming and its scope in India?
5. What are the issues in Indian Aquaculture?
6. What do you mean by climate resilient aquaculture?
7. Write about technological and developmental initiatives
8. What are the various issues in marine fisheries management?
9. What are the measure needs to be taken for sustainable marine fisheries development?

3.A.14 FURTHER READINGS/ REFERENCES

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UNIT 3: SUSTAINABLE FISHERIES DEVELOPMENT
B. PROCESSING AND VALUE ADDITION IN FISHERIES

Highlights of the Unit

- Objectives
- Introduction
- Fish consumption trends
- Indian fish production and export
- Importance of efficient and hygienic fish handling and transportation network
- Fish processing and value addition
- FSSAI standards and guidelines
- Financial support and state-specific action plan
- Let's sum up
- Check Your Progress
- Further readings

3.B.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Fish consumption trends
- Indian fish production and export
- Importance of efficient and hygienic fish handling and transportation network
- Fish processing and value addition
- FSSAI standards and guidelines

3.B.1 INTRODUCTION

Fish and fishery products play a critical role in global food security and nutritional needs of people in developing and developed countries. During 2015, fish accounted for about 17 % animal protein consumed by global population. Fish provided about 3.2 billion people with almost 20% of their average intake of animal protein. Despite their low level of fish consumption, people in developing countries have a higher share of fish protein in their diets than those in developed countries.

The nutritive value of fish is well documented and is one of the cheapest animal proteins. Consumption of fish provides energy, protein and a range of vitamins and minerals. Furthermore, fish has a particular role as a source of the long-chain omega-3 fatty acids *e.g.,* Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA), which are important for optimal brain and neural system development in children. Evidences

underline role of fish in lowering the risk of coronary heart disease (CHD). Fish is also an excellent source of micro-nutrients, vitamins and minerals.

Fish is highly perishable food item. From the moment fish is harvested from the water, the bio-chemical reactions and microbial growth will result in drastic changes in the body of fish. This process is broadly called as 'spoilage of fish' as undesirable smell and softness in body tissue of fish will hamper cooking, affect the taste and consumption by public. Further, some of these reactions will result in degradation of nutritive value of fish. Thus, the quality fish starts degrading from the moment fish is harvested from the water. Factors like external injuries due to improper handling of fish, poor quality of water used for cleaning, contaminated place of storage etc. will hasten the process of spoilage of fish.

Considering the nutritive value of fish and its importance in human food, all issues related post-harvest operations inclusive of hygienic handling, transportation, storage, processing, value addition, marketing, safety standards for fish as food etc. have to considered by Fisheries Managers policy makers and other related stakeholders. Creation of appropriate awareness among consumers is essential.

3.B.2 FISH CONSUMPTION TRENDS

Global food fish supply has grown steadily in the last five decades, at an average annual rate of 3.2 %, outpacing world population growth (1.6 %). World per capita apparent fish consumption increased from an average of 9 kg in the 1960s to 17.00 kg in the 2000s, and to 20.20 kg in 2015, at an average rate of increase of 1.5% per year. In the Indian perspective, fish consumption has increased as a result of increase in production and inclination towards fish for its health benefits. During 2015, the Indian per capita fish consumption was estimated at about 5.39 kg for total population and 7.70 kg for non-vegetarian (70% of total population, NSSO) which was far lower than world average. The driving force behind increased fish consumption in India has been a combination of population growth, rising incomes, and urbanization interlinked to the strong expansion of fish production and modern distribution channels.

3.B.3 INDIAN FISH PRODUCTION AND EXPORT

Indian fish production: Indian fish production has increased significantly during last 10 years. The increase is mainly coming from Aquaculture. During 2017-18 the total Indian fish production was estimated to be 126.10 lakh metric ton comprising of 36.93 lakh metric tons of marine fish and 89.17 lakh tons of freshwater fishes. During the same year, India has exported 13.77 lakh metric tons of fishes, which was about 10.92% of total fish production in the country. The remaining nearly 90% of the fish is utilized within the country.

Export of fish and fishery products from India: Fishery export accounts for around 3% of the total exports of the country and nearly 20% of the agricultural exports. During the financial year 2013-14, exports of fish and fishery products reached to 9, 83,756 tons valued

at Rs. 30,213.26 Crore. The increased production of *Litopenaeus vannamei* shrimp has helped to achieve higher exports. During 2017-18 the export of seafood reached all-time high 13, 77, 244 tons valued at Rs. 45106.89 Crore.

Table 1. Showing total Indian fish production and export details

Year	Total fish production (lakh tons)	Total Export (lakh tons)	Exported (as % of production)	Export value (Rs. in Crore)
2012-13	90.40	09.28	10.27	18,856.26
2013-14	95.79	09.84	10.28	30,213.26
2014-15	100.69	10.51	10.44	33,441.61
2015-16	107.90	09.46	08.77	30,420.83
2016-17	114.10	11.35	09.95	37,870.90
2017-18	126.10	13.77	10.92	45,106.89

(Source: DADF, New Delhi and MPEDA, Kochi)

3.B.4 IMPORTANCE OF EFFICIENT AND HYGIENIC FISH HANDLING AND TRANSPORTATION NETWORK

As mentioned earlier and as evident from the information/data presented in Table 1 only about 10% of total fish produced in India is exported. This indicates that nearly 90% of fish produced in India is utilized within the country. The state-wise fish production data for 2014-15 indicates that 73.31%of total marine fish of the country is landed in four states namely Gujarat, Kerala, Maharashtra and Tamil Nadu. Similarly, about 61.35% of the total inland fish production of the country is produced in four states namely Andhra Pradesh, West Bengal, Uttara Pradesh and Bihar. Further, the marine fishes are landed at a few Fishing harbors and landing centers along the coast of the country. Most of the states, including North-Eastern states where fish is a predominant source of protein, are fish deficit states. Further, nearly 70% of fish produced in India is marketed as fresh whole fish, with or without ice, and with no processing. Hence, there is an enormous responsibility to develop an efficient and hygienic handling, packing, transportation and marketing network for fresh, dried or processed fish from the production / landing area to towns and villages across the country for the benefit of consumers.

The hygienic and efficient fish marketing network will also help in reducing the post-harvest losses, in retention of nutritional quality of fish, and continuous (throughout the year and all throughout the day) supply of quality fish under hygienic conditions to consumers resulting in increased consumption of fish. Further, it will assist fishermen and fish farmer to realize better price for their produce and in creation of additional employment.

3.B.5 SPOILAGE OF FISH

Fish is a highly perishable food. The spoilage of fish, both by enzymatic degradation and by microbial growth can be arrested by lowering the body temperature of fish close to 0^0 C. Transportation of fish, that is chilled to close to 0^0 C, under constant temperature of 0 to 4^0 C will help in prevention of spoilage and also in retention of the nutritional quality of the fish. Generally, fish is transported with ice in crates. For long distance transport, fish traders used to cover the top of the fish load with extra ice and with tarpaulin sheet. In many cases paddy husk or even thermocol (polystyrene) sheets are used. However, owing to constant exposure to ambient hot air, the packed ice in outer layer of crates used to melt, leading to increase in the body temperature of fish and spoilage of fish. Hence, in the recent years the insulated trucks are used to transport the fish with ice over long distance.

3.B.6 FISH PROCESSING AND VALUE ADDITION

The term 'fish processing' refers to any post-harvest activity either for human consumption or for industrial purposes. India is one of the leading fish processing and exporting country in the world. The data provided in the Table 1 clearly indicates the progress achieved in export of fish from the country.

There are about 572 fish processing units in the country, processing the shrimp and fish to the international standards mainly for export to United States of America, European Union, Japan, South East Asian countries, Japan etc. All these units are established for processing of fish and shrimp mainly for export market and very less for domestic market.

The Indian marine export is dominated by frozen shrimp and frozen fish. During 2018-19, frozen shrimp constituted 68.43% of total value of Indian marine exports and 41.10 % of total volume. The other important export products are frozen fish (10.36% of total value and 25.64% of total volume), frozen cuttlefish, frozen squids, dried items, live fish and chilled fish. However, in the recent years some processers like M/S Amalgam, Kochi, Gadre Marines, Ratnagiri, Mulpuri fisheries, Vijayawada etc. are processing fish for domestic market. The processed and packed fish is also made available to consumers in retail marketing units of M/S Metro Cash & Carry, Spar, Big Bazar and other departmental stores.

The changing life style of people, especially in metros, is demanding the supply of processed fish for consumption of house-holds. Owing to lack of time to clean, cut and cook, and inadequate facilities for disposal of fish waste, particularly in residential apartments, the public are purchasing processed fish in the form of cut, cleaned, chilled or frozen fish; ready to cook and ready to eat fish products. Lack of efficient cold-chain, lack of infrastructure, preference for whole fish by majority of consumers are primary reasons for limited demand for processed fish products.

3.B.6.1 Chilling of fish: The shelf-life of fish can be increased by reducing the body temperature of fish to near to Zero degree centigrade, where in the enzymatic and

biochemical reaction, and bacterial growth gets reduced. Hence, chilling of fish using ice/ ice-slurry/ chilled water is an important practice in preservation of fish. The chilling of fish must start immediately after taking fish out of water. There should not be any delay. The practice of placing the harvested fish in ice water is very good to retain the quality of fish. Similarly, the fish must be kept at lower temperature till it is used for cooking. However, there is a misconception among the consumer that 'the iced fish is not fresh'. An awareness has to be created among consumers on importance of lowering the body temperature of fish and on use of ice.

Chilled fish is stored in cold storages (4^0 C) with ice. Dehydration is one of the issues that has to be taken care during handling, transportation, storage and display for sale. Storage of fish with ice in insulated boxes for short period is a good practice as ice not only lowers the body temperature, but also keeps the moisture on the body surface of fish. In most of the retail outlets, deep freezers are used for storage of fish. However, caution has to be taken to avoid freezing of fish in the deep freezers.

3. B.6.2 Freezing of fish: Freezing is a widely used fish processing method all over the world. The fish is quickly frozen to - 30^0 C and stored at a temperature of less than -18^0 C. Degutted whole fish, fish steaks, fish fillets are frozen in blast freezers or plate freezers and packed for sale. Individually Quick Freezing (IQF) is also practiced in recent years.
Generally, frozen fishes are not readily accepted by consumers in India. However, frozen shrimp and frozen 'basa' (Pangasius) fillets are used mainly by restaurants. Lack of sufficient frozen storages across the country, frozen fish transportation and delivery system, display cabinets at consumer point, additional cost on power are some of the important draw backs in production and marketing of frozen fish/ shrimp. In the absence of continued power supply in most part of the country, operation of an efficient cold-chain is a challenge. Further, awareness among consumers on thawing & handling of frozen fish, avoiding refreezing of thawed fish and usage of freezer compartment of house hold refrigerator for freezing of fish has to be created. In spite of all these challenges, development of cold-chain for supply for production and supply of frozen fish across the country, especially from fish-rich states to fish deficit states. Further, such a cold-chain will also help in handling and marketing of large-scale fishes harvested during peak season in marine fisheries or from intensive aquaculture units like cage culture, Re circulatory Aquaculture systems (RAS) etc. thorough out the year.
Many state fisheries federations and corporations are involved in these activities. However, it is imperative to encourage the private sector in establishment and operation of cold-chain for fisheries across the country.

3. B.6.3 Canning of fish: Canning of cooked marine fishes like sardine, tuna, mackerel etc is also another important method of processing. Owing to cost and eating habits, canned fishes are not popular in the country.

3. B.6.4 Retort Pouched Products: A retort pouch is made from multiple layers of flexible laminate, allowing for the sterile packaging of fully-cooked, thermo stabilized (heat - treated) Ready-to-Eat (MREs) fish products which can be eaten cold, or warmed by submersing in hot water. The fish is first prepared, even raw or semi-cooked, and then sealed into the retort pouch. The pouch is then heated to 116 - 121^0 C for several minutes under high pressure inside retort or autoclave machines. The fish inside is cooked similar to pressure cooking. This process reliably kills all commonly occurring micro-organisms preventing fish from spoilage. The packaging process is very similar to canning, except that the package itself is flexible.

3. B.6.5 Fish drying: Fish drying is a traditional way of processing and preservation of fish in the country. Dried fish is extensively consumed in coastal areas and in North-Eastern states. Jagiroad dry fish market in Assam is one of the largest dry fish markets not only in India but also in Asia. Dry fish is procured from different fishing villages across the coast and sold to consumers in North Eastern states. Fish drying is also an important employment and income generating activity, especially for fisherwomen in coastal areas and near reservoirs.

Although dry fish production and marketing is an age-old practice, the quality of dry fish has not received much attention resulting contamination and denaturation of fish leading to poor quality and loss of nutritional value. Hence, greater emphasis must be given to quality of fish production through adaptation of better handling, use of clean water, good quality salt, use of racks for sun drying, avoiding drying on sand, use of appropriate packaging method, branding and marketing. Central Institute of Fisheries Technology (ICAR - CIFT), Kochi has developed solar fish dryers which will facilitate in dry fish production at optimum temperature, without any contamination, impurities and bad smell. The quality of the product will be excellent and it will attract better price in the market.

Fishers traditionally produce various fish products by fermentation, salting, drying and smoking for preservation and storage. The microbial contamination and loss of nutritional value are the major concerns. It is advisable to create awareness among fisher folk on hygienic handling fish, health benefits of fish consumption, packaging of fish and fish products and on Food Safety and Standard Authority of India (FSSAI) regulations & guidelines.

3.B.6.6 Fish meal and fish oil production: Marine Fishes**,** especially pelagic fishes in West Coast having less market value are used for production of fish meal and fish oil. Fish meal is an important ingredient in fish / shrimp feed and poultry feed production. With the increase in area and production of shrimp in India, the demand for fish meal has also increased. However, sufficient fish is not available for fish meal productions. Care has to be taken to avoid harvesting of juvenile fishes and its usage for fish meal production.

3.B.6.7 Surimi products: A washed, refined and stabilized fish mince, a process originally developed in Japan to provide an intermediate and relatively stable frozen material

suitable for the subsequent production of traditional kamaboko products. Preparation of surimi is a means of intensifying the gelling properties of fish protein and of preserving these properties during frozen storage. Generally, low value marine fishes like pink perches are used for production of surimi.

3. B.6.8 Ready to cook and ready to eat products: The Research and Development (R & D) institutes like CIFT, Kochi have developed various fish products which are ready to cook or ready to consume. There are products like battered and breaded products (coated fish fillets, fish fingers, fish balls, fish cutlets, coated products from prawn), fish sausages, fish biscuits, fish wafers etc.

There are wide regional variations in the recipe for fish preparation and the consumer preferences. Hence, many of these fish products have to be prepared based on local need. The ICAR- CIFT, Kochi is operating 'Business Incubation Centre' for production and test marketing of fish products. The entrepreneurs will be provided with office space, guidance on product preparation, and packaging, branding, marketing, guidance on firm registration and on obtaining necessary permissions and licenses from competent authorities. All equipment's for fish product preparation can used on rent. It is good model for entrepreneurship development.

R & D institutes have also developed many health products/ nutraceutical products from fish and sea weeds. Fish body oil, shark liver oil etc. are very popular across the world. There is a vast scope to develop many of such products with the technical support of R & D institutions.

3. B.6.9 Value addition and Processing in Freshwater Aquaculture: Bony fishes including Indian major carp (*Labeo rohita Catla and Cirrhinus mrigala)* and Chinese carps *(Cyprinus carpio*), *Ctenopharyngodon idella* and *Hypophthalmicthys molitrix*) form a major component of carp aquaculture. Carp is the most consumed freshwater fish species in the world. Due to its high nutritive value, it plays an important role in human diet. Large quantities of carps are consumed fresh as whole fish or cut –up-parts (Sahu, 2017). The carps have however, has less market value due to presence of intramuscular bones, which reduces their consume acceptability. Thus, the need was felt to develop some bone less convenience products for enhancing the consumer acceptability of carps.

Sensory evaluation of the products gave highly encouraging results. The method of deboning carps and value-added carps' products were transferred to some women self-help groups for empowerment and employment generation. The effort was to create a domestic and an international market for the fish as a low cost, boneless, healthy, value added pre-cooked and flavored fish product acceptable to consumers. Carp have no value sold as whole fish. Carp must be deboned and processed into value added products to be a valuable commodity that can be sold in the retail grocery and institutional food markets. With the changing requirements and habits of the consumers the need for an increased market supply of ready-to-cook (fillets, nuggets, chunks etc.) and ready-to-serve (battered, breaded and fried fast food products) have come to fore front.

A need for high quality, convenience carp product is growing, especially in the more affluent population. Processing of carps is a new progressive development which opens new markets and enlarges the present demand. There are many post-harvest methods by which freshwater aquaculture fishes can be as value added products. Extensive awareness and training are required to create awareness in promoting value addition in freshwater fishes.

3. B.7 HYGIENIC MARKETING OF FISH

Generally, fish is sold on the road side markets with very little emphasis on hygiene. There are only a few fish markets which have basic infrastructure for hygienic handling and marketing of fish. Since 2010, National Fisheries Development Board, Hyderabad under the Department of Fisheries (earlier Dept. of Animal Husbandry, Dairying and Fisheries), New Delhi has actively assisted state fisheries departments, local city corporations and municipalities to establish and maintain hygienic fish markets. These markets normally have dedicated fish market building with compound, gate, cow trap, parking area, fish unloading area, water & power supply, raised platform for display, trading and cutting of fish, wide passage within the building, washable floors and walls, drainage, insect repellents, waste disposal system, effluent treatment plant, wash rooms etc. Other facilities like ice production units, chilled storage facilities, dry fish trading markets, fisherwomen rest rooms etc. can be constructed in the fish market depending upon the demand and availability of land. Further, sufficient revenue must be generated from the market and it has to be managed and maintained under hygienic conditions. There has to be a monitoring program on management and maintenance of fish markets. Further, creating awareness among stakeholders on hygienic fish marketing, and their role and responsibilities is required.

3.B.8 FSSAI STANDARDS AND GUIDELINES

The quality of fish during fish handling, transportation, storage, processing and marketing operations have to maintain certain standards as per 'Food Safety and Standard Act, 2005'. Food Safety and Standard Authority of India, New Delhi (FSSAI) has published various guidelines and rules for handling and trading of fish and fish products (Ref 2). FSSAI is also operating programs on 'Food Safety Training and Certifications' (FoSTaC). All fish processors, wholesale and retail traders, fish kiosks etc. have to obtain license from FSSAI. The fisheries officers in association with FSSAI, New Delhi and state level food inspection authorities must organize awareness creating programmes and trainings for all stakeholders including fishermen and fish traders. Details can be obtained from the website *www.fssai.gov.in*and *www.fostac.fssai.gov.in*.

3.B.9 FINANCIAL SUPPORT

Considering the importance of establishing hygienic cold-chain, Government of India in collaboration with state Governments, is supporting for establishment of cold-chain and for various components of cold-chain. Some of the important programs are listed below:

a. Ministry of Food Processing Industries (MoFPI, New Delhi): Financial assistance is provided under 'Pradhan Mantri Kisan Sampada Yojana' - (i) 'Cold-chain' (ii) 'Processing / Preservation' (iii) 'Food Safety and Quality' etc. (web: www.mofpi.nic.in).
b. National Fisheries Development Board (NFDB), Hyderabad – The assistance is provided under CSS- Blue Revolution: Integrated Development and Management of Fisheries (Ref 3) for Construction of ice plants, cold storages, modernization of ice plants/ cold storages, hygienic fish transportation infrastructure, development of fish markets, mobile retail fish outlets, kiosks etc. Further, NFDB directly supports for establishment of 'Integrated Cold-chain' for fish.
c. Department of Fisheries, Ministry of Animal Husbandry, Dairying and Fisheries, Government of India has recently launched a program called 'Fisheries Infrastructure Development Fund' (FIDF) for assisting creation of infrastructure for fish culture and post-harvest activities.
d. Many State Fisheries Departments are supporting various components of cold-chain under Rural Infrastructure Development Fund, Rastriya Krishi Vikas Yojana etc.

3.B.10 STATE-SPECIFIC ACTION PLAN

a. It is evident that efficient and hygienic cold-chain inclusive of processing and value addition has to be developed near all fish producing and fish consuming areas. In order to do that it is required to prepare a state-specific or area/ region - specific action plan for creation of infrastructure and to develop skill among stakeholders. Action plan has to be prepared based on quantity of fish production, availability of land, water, power and skilled manpower and market demand. The important areas to be covered under action plan are as follows:
b. Development of hygienic fish handling and storage facilities on board fish vessels, especially small motorized and non-mechanized fish vessels, and faster fish landing facility in reservoirs and tanks in order ensure supply of quality fish.
c. Development and maintenance of hygienic fishing harbour and fish landing centres, creation of waste disposal system, adequate water and electricity facility in them
d. Establishment and maintenance of post-harvest infrastructure facilities like ice plants, chilled storage facilities, mechanized hygienic ice handling and loading facilities, Insulated / refrigerated fish transportation facility etc. Construction of fish landing centres in reservoirs with ice production and fish handling facilities.
e. Establishment of Cold chain, processing & marketing facilities - construction of fish processing units, frozen & chilled storages and transport facilities for fresh, dressed, dried and processed fish; establishment of units for utilization of fish waste;

construction of hygienic fish markets for trading of fresh, dressed, processed and value- added fish and fish products etc.

f. Establishment of model fish processing centers with training facilities and quality assessment laboratory for production of value-added fish products by entrepreneurs.
g. Production, packaging, storage and marketing of value-added fish products including production of fish pickle and dry fish by fisherwomen.
h. Awareness, campaign & Branding – Awareness and campaign on health benefits of fish consumption; Branding and trading of fish and fishery production
i. Training **–** Training on hygienic fish handling on board the fishing vessels, at fish landing centers and fishing harbors. Training also on food safety standards etc.; Training on management and maintenance of fish markets and handling of fish to fish traders and other persons involved in handling of fish. Training on production and marketing of value-added fish products, food safety standards, food processing and packaging regulations, entrepreneur's development programmes etc.
j. Establishment of fishery industrial estates, close to the fishing harbors / fish landing centers / fish production clusters for handling and processing of fish in a hygienic manner, utilization of fish by-products and waste and provision of ancillary support services etc.

3.B.11 LET'S SUM UP

Fish processing and value addition is an important sector for development of fisheries, generation of employment, reduction of post-harvest losses, realization of higher income for fishers and for supply of quality fish and fish products to consumers.

3.B.12 CHECK YOUR PROGRESS

1. Enumerate fish consumption trend in India?
2. Describe the scenario of Indian fish production and export?
3. State the importance hygienic fish handling and transportation?
4. Fish processing and value addition
5. FSSAI standards and guidelines
6. State-specific action plan

3.B.13 FURTHER READINGS/REFERENCES

1. Training Manual on SEAFOOD VALUE ADDITION, 2018. Published by ICAR-CIFT, Kochi
2. Guidance Document - Food Safety Management System (FSMS) - Food Industry Guide to Implement GMP/GHP - **Fish and Fish Products –** Published by FSSAI, New Delhi (2018) (First Edition May, 2018; Online available at *www.fssai.gov.in*)
3. Guidelines – CSS on Blue Revolution: Integrated Development and Management of Fisheries. Department of Animal Husbandry, Dairying and Fisheries, Govt. of India. Published by National Fisheries Development Board, Hyderabad; (Revised Print 2018; Online: *www. ndb.gov.in*)

UNIT-4: MISCELLANEOUS ENTERPRISES FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT

Highlights of the Unit

- Objectives
- Introduction
- Importance of miscellaneous enterprises
- Miscellaneous enterprises – Mushroom cultivation, Sericulture and Apiculture
- Sericulture
- Apiculture
- Let's sum up
- Check Your Progress

4.0 OBJECTIVES

After completing this unit, the learners will be able to understand

- Know the importance of miscellaneous enterprises
- To know about mushroom cultivation, sericulture and apiculture as agribusiness enterprises

4.1 INTRODUCTION

The ambition of doubling farmers' income by 2022 in India has led to focused discussion on the possibilities and ways to achieve it. The Indian Government has emphasized with a seven-point strategy to make the doubling of farmers' income a reality. One important strategy among the seven strategies is to focus on the miscellaneous enterprises (Secondary agriculture) as they largely remain underrated. In the backdrop of diverse agriculture scenario in India, agriculture and animal husbandry remain a dominant means of livelihood. There are many miscellaneous enterprises which can complement the agriculture and animal husbandry activates needs immediate attention in India. Mushroom cultivation, sericulture, apiary, vermicomposting, value addition and processing of vegetables and fruits etc. can be substantial avocations in different regions for sustainable agriculture development.

4.2. IMPORTANCE OF ENTERPRISES

The need for miscellaneous Agri-enterprises emerge also from the fact that, the demand for land by other sectors has led to reduction in the share of arable land to 52.80 % (2013) from 55.00 % in 1985. Coupled with increasing pressure of population, the per capita land availability in India has reduced from 0.34 ha in 1961 to 0.20 in 1985 and further down to

0.12 ha in 2013. The similar trend for few more years will put increasing pressure on land availability which can jeopardize the sustainability of Indian agriculture.

The sustainability in agriculture is complete only when the enterprise is economically profitable, socially compatible and ecologically safe. Now the modern agriculture commercial crop-based enterprises are achieving the above three objectives partially. On the contrary, the miscellaneous enterprises are being explored as alternate options to practice the sustainable farming practices. Majority of the miscellaneous enterprises put least pressure on land area and yield higher economic returns. Further, such practices are helping in recycling the farm wastes and are socially compatible in the Indian society. Three such important miscellaneous enterprises; Mushroom cultivation, apiculture and sericulture which can be part of miscellaneous activities for sustainable agriculture are discussed in this chapter.

4.3 TYPES OF ENTERPRISES

4.3.1 Mushroom cultivation: Mushroom cultivation is as an important agri-business activity for practicing sustainable agriculture especially for rural dwellers. It is also noted that urban dwellers have also adopted mushroom cultivation as an enterprise. It is also a reliable source of additional income for farm families. Mushrooms are a rich source of proteins and vitamins. Different varieties of mushrooms are cultivated mostly depending on the climate and consumer demand. Few of the important cultivated edible mushrooms are button mushroom (*Agaricus bisporus*), shiitake mushroom (*Lentinula edodes*), milky mushroom (*Calocybe indica*), oyster mushroom (*Pleurotus* sp), Paddy straw mushroom (*Volvariella volvacea*) etc.

Mushroom cultivation is practiced in different models and scales, depending on the type of variety and objective of production. The button mushroom is usually produced in large scale seasonal huts or environment-controlled units, while the tropical mushrooms like oyster mushroom, milky mushroom and paddy straw mushrooms are grown in medium to small units. To give the detailed account of all the mushroom varieties is beyond the scope of this chapter. However, information given below will help you to get the primary understanding about the commercial cultivation of few important edible mushrooms.

Calocybe species (milky mushroom or "*dudhiya*" mushroom) and *Pleurotus* sp (Oyster mushroom or *dhingri* mushroom) are most suitable for Indian conditions because of their wider adaptability to tropical climate and different substrates, easy cultivation technique and high productivity. Both these mushrooms are also a good choice for inexperienced and start-up cultivators because they are easier to grow than many other species requiring moderate initial investment.

a. Cultivation method: The cultivation of all mushrooms is practiced with similar growing principles but making some adjustments as per the biology of the specific mushroom variety. The differences are on spawn rate/dose, casing steps followed in case of button mushroom and milky mushrooms, and different growing temperature in different stages of crop. The major steps common to all mushrooms are discussed below.

b. Preparation or procurement of spawn: Spawn is the seed of the mushroom which is mass of fungal mycelium grown on cereal grains such as wheat, Jowar, Bajra, *etc*. The process of spawn production involves various steps from pure culture selection, isolation, multiplication on synthetic media followed by preparation of mother spawn and then commercial spawn. Entire process of spawn production is to be done under hygienic conditions to avoid contamination of spawn with other harmful microorganisms. The cost of establishing the spawn laboratory may range from 15-40 lakhs for a commercial unit depending on the quantity of spawn produced and type of machinery used.

Since the spawn production requires certain machinery such as laminar flow, autoclave and incubators small farmers will find it unaffordable. Alternatively, they can purchase the spawn from various spawn producing laboratories situated nearest to their mushroom unit. Many Krishi Vigyan Kendra (KVK) and State departments of Agriculture/Horticulture also supply the spawn at subsidized rate to the mushroom growers. Apart from them there are enterprises owned by farmers also produce mushroom spawn. In Odisha mushroom spawn is mostly supplied by private sector like farmers and entrepreneurs.

c. Substrate preparation or substrate pasteurization: Substrate is the pre-requisite for the mushroom cultivation. The substance on which the mushroom grows. Different varieties of mushrooms grow on different growing media/ substrate. Some mushroom varieties (Milky and oyster mushroom) are grown on simple pasteurized agriculture residues while the button mushroom, brown button mushroom are grown on composted material. In such cases, the composting of the material take different time based on the method of composting. In the traditional practice of long-method of composting, it takes 28-30 days for compost to be ready for spawning. In case of short method and indoor method of composting, 14-16 days are required. The short method/ indoor method of composting makes use of bulk chambers and pasteurization tunnels which facilitate the regulation of fresh air and temperature in the compost. Some of the wood rotting fungi such as shiitake, ganoderma and flammulina can be grown on synthetic substrate made from suitable saw dust mixed with 18 per cent wheat bran and 1-2 per cent gypsum (By weight basis) sterilized in autoclave.

Milky and oyster mushrooms can be cultivated on a large number of agro-wastes such as cereal straw, sugarcane bagasse, saw dust, jute and cotton waste, dehulled corncobs, pea nut shells, dried grasses, *etc*. Many spawn producing firms are selling ready to fruit bags by mixing the spawn with the substrate. This is an easiest way to gain the confidence in mushroom cultivation. Dry agricultural waste or residue that is usually wheat straw, paddy straw, mustard straw, sugarcane bagasse or combination of these substrates are selected that can support the growth of any mushroom.

While selecting the agriculture residue, ensure that the straw is not too old and not exposed to rains or dust as it may be susceptible to attract the contamination. But one of the difficulties in getting straw due to mechanized harvesting is an issue. It should also be completely dry and do not have any green leafy portion. Pasteurization, composting

or the sterilization of any agricultural residue is primarily aimed at facilitating quick colonization of mushroom mycelium in the substrate by killing of harmful competitor moulds and fungi. All these processes help in killing the microorganisms primarily through the exposure to heat. The details of straw pasteurization, spawning and bag filling for oyster and milky mushrooms are presented through fig. 1.

d. Spawning: Quality spawn will make mushroom cultivation effective and profitable. Hence, one has to ensure the quality of spawn. Freshly prepared, matured grain spawn is mixed with the pasteurized/ composted substrate. The spawn rate differs with different mushrooms. It is 0.75 per cent in case of button mushroom, 3-4% in case of oyster mushroom and @ 4-5% in case of milky mushroom on wet weight basis. The spawning should be done under clean and hygienic conditions, preferably in rooms pre fumigated with formaldehyde to prevent the entry of competitor molds.

Spawning can be done either by thoroughly mixing the grain spawn with the substrate or by spreading in layers of pasteurized substrate and the spawn alternatively. After the spawning process, the spawned substrate will be filled in the polythene bags and tightly pressed and tied with a nylon rope. Though the farmers practice the bag filling from in varying weights, 4-5 kg filled bags are reported to be giving higher biological yield in milky and oyster mushrooms. For button mushroom, the bags may be of 10-15 kg and some units even keep 20-25 bags and also practice shelf method of cultivation. Ten to fifteen small holes should be made on all sides of the bag to facilitate the aeration, drainage of excess water and also to maintain the optimum temperature.

After the spawning, the bags are kept in suitable conditions with appropriate temperature and humidity for different mushrooms for spawn running. In the spawn running, the mushroom fungus present in the mushroom seed will start developing the mushroom mycelium in the compost. Depending on the conditions prevailing and the mushroom variety the spawn running will complete in 15-20 days. After this they are exposed for cropping conditions. In case of button mushroom and the milky mushrooms, casing soil is to be put on the spawn-run compost to allow the mycelium to grow in the casing soil (Case run).

e. Crop establishment and management: After the spawning, the crop management practices start which includes environment management in the cropping rooms and additionally the casing soil preparation, casing soil application are done in button and milky mushrooms. Finally, after the maturity of fruiting, the harvesting and the post-harvest operations are done.

The oyster mushroom bags are either hanged from the ceiling in 3-5 tiers (Fig. 2) or placed over the shelves. The room temperature during the spawn run is maintained to suit the type of mushroom variety selected. For most of the tropical oyster mushrooms varieties, 25-30°C is maintained for spawn run and fruiting (Table 1). In case of milky mushrooms, the bags are kept in the incubation room or cropping rooms (Fig. 3) which are mostly dug 3-4 feet below the ground level (Fig. 4). Ideally the temperature is maintained between 25-30°C for better spawn running. Higher temperature such as more than 30°C in the cropping room will inhibit the growth and might kill the mycelium.

Table 1. Temperature requirement of some important cultivable mushroom species

Variety	Spawn-run temperature	Fruiting temperature
Tropical mushroom species		
Milky mushroom	25-30	34-38
Ganoderma mushroom	25-32	35-40
Pleurotus sapidus	25-30	22-26
P flabillatus	25-30	20-26
P membranaceous	25-30	22-28
P djamor	26-32	28-30
Sub-tropical mushroom species		
P ostreatus	22-26	14-20
P ostreatus var. *florida*	22-28	14-22
P cornucopea	24-28	18-22
P sajor caju	25-30	18-26
Temperate mushrooms		
White button mushroom	16-18	21-25
Brown button mushroom	18-22	25-28
Flammulina sp.	08-12	10-15
P eryngii	18-22	14-20

During mycelial growth, the bags are not to be opened as they do not require much ventilation. Around 60-80 per cent relative humidity is maintained. Water spray is not necessary during the spawn run stage. In about 15-18 days the spawn running will be complete. When the spawn running is delayed because of unfavorable conditions, wait for few more days so that maximum spawn running is observed in majority of the bags.

After the spawn running is complete, the fruiting can be induced by giving fresh air, increasing the relative humidity and exposure to diffused light to the oyster mushroom bags. With change in these environmental conditions, the oyster mushrooms start giving the fruiting.

As mentioned above, in case of button mushroom and milky mushrooms, an additional step of application of casing soil is followed. The compost bags which are fully colonized with mushroom mycelium are taken for casing soil application.

A. Casing soil and its preparation: Casing is the process of covering the spawn run compost with a layer of pasteurized casing soil. The casing soil is necessary for the fruiting of some mushrooms like button mushroom, milky mushroom and macrocybe mushrooms. Casing soil serves three important functions like, providing physical support to mushroom fruit bodies, regulation of flow of nutrients from compost to developing mushrooms and act as a reservoir of moisture for the mushrooms.

Different formulations are practiced to prepare the casing soil. Some of the frequently practiced casing soil formulations are;

- Mixture of 2 years old FYM and 2 years old spent mushroom compost in 1:1 ratio
- Mixture of Garden soil and sand mixture in 1:1 to 4:1 ratio by volume or
- Decomposed FYM and loam soil in 1:1 by volume

The prepared casing soil is treated either by steam at 65-70^{o}C for 6-8 hours or by drenching with commercial grade formaldehyde or formalin @ 3 liters in 40 liters of water per cubic meter casing soil. The pH of casing soil must be adjusted to 7-8 with the addition of calcium carbonate commonly known as chalk powder. Besides the pH, good casing soil should have High Water Holding Capacity (WHC), high porosity and nutritionally poor.

Such a casing soil is applied for about (2-3 cm thick for milky mushroom and 3-4 cm for button and macrocybe mushroom) over levelled / fully spawn run compost, uniformly. Very light water spraying should be given immediately after casing soil application to make the casing soil wet. During the case run, the room temperature must be maintained at 32-35^{o}C temperature and a relative humidity of about 90%. In the case-running phase, the mycelium gets colonized in the casing soil. This may take around 7-10 days' time depending on the cropping room conditions. Once the mycelium has fully colonized the casing soil, it forms a thick mycelial mat on the casing soil and is ready for fruiting. Any Contaminated bags with mold infestation should be discarded. All the bags are arranged on iron/wooden platforms or shelves adjacent to each other in the iron shelves.

B. Environmental parameters for fruit body development: The casing soil moisture must be maintained by spraying water accordingly and sufficient ventilation should be provided for air circulation. The room temperature of fruiting (eg. 32-35^{o}C for milky mushroom, 16-18 ^{o}C and a relative humidity of about 90% must be maintained at this stage. With these conditions, the mushroom mycelium turns into reproductive phase to give rise to the small pinheads- which develop into matured fruiting bodies in few more days. The pH of the water used for spraying should be neither too acidic nor alkaline and it should not contain harmful salts. The neutral pH is preferable.

4.3.2 Harvesting and post-harvest handling: With suitable crop management practices, mushroom fruit bodies are ready for harvesting in 6-8 days after pinheads' formation (Fig. 5). The right stage for picking can be judged by the shape and size of fruit body. It is advisable to harvest all the matured mushrooms at one time from a bag so that the other pin heads in the bags develop into mushrooms. The best quality mushrooms can be harvested from the first and second flush crop due to the availability of sufficient nutrients. Under normal room temperature conditions, the harvested fresh mushrooms can be stored for 2-3 days without any deterioration.

4.3.3 Economics of house hold mushroom production: The Ready to Fruit (RTF) spawned bags are sold by the commercial mushroom/ spawn growers @ Rs. 40-150 depending on the quantity of the straw and prevailing price of straw and fresh mushrooms in the local market. Each bag of 5 kg wet straw should ideally give about 1.5-

2.0 kg fresh mushrooms in three to four pickings at an interval of 6-10 days. Interested entrepreneurs can also start the sale of such ready to fruit bags by motivating the people who show interest to consume the home-grown fresh mushrooms for their household nutrition security and additional source of income generation.

4.3.4 Economics of commercial mushroom production: The discussion on economics of all edible mushrooms is beyond the scope of this chapter as each mushroom is having different commercial models requiring different infrastructure. The cultivation technology of milky and oyster mushroom is very simple requiring modest infrastructure facilities in the tropical climate. For the production of 40-50 kg fresh mushrooms per day, minimum of four low cost growing rooms may be constructed. The dimension of the room may be of 20x15 feet or 18X30 feet depending on whether the cropping bags are arranged in one tier, two tier or three tier. These rooms can be made from Bamboo, high density poly sheets or of permanent structures. Depending on the type of materials used for construction, the milky mushroom unit may cost Rs. 12-18 lakh. The ICAR-Directorate of Mushroom Research, Solan and its coordinating research centers in different states will help in providing technical knowledge through frequent trainings and preparing the project report for financial assistance and subsidy from the banking institutions and National Horticulture Board respectively. Farmers and entrepreneurs can avail the subsidy of National Horticulture Board and other developmental departments like State Department of Horticulture in the respective districts of the state.

Fig. 1 Steps in preparation of oyster and milky mushroom beds

Fig.2 Substrate mixed with mushroom spawn in polythene bags kept for spawn run

Fig. 3 Commercial milky mushroom unit

Fig. 4 Individual milky mushroom hut

Fig. 5 Harvesting of fully matured milky mushroom fruiting bodies

4.4 SERICULTURE

Sericulture is another important miscellaneous agriculture-based enterprise which deals with the production of silk by rearing of silkworm. The silkworm (*Bombyx mori* L.) is domesticated for silk production for about five thousand years. Since the legendary fall and unraveling of a cocoon in the teacup of Chinese princess Xi Ling shi, the mulberry silkworm has been intimately connected with humans. Besides supporting the farmers' livelihood, sericulture also supports the workers in the textile industry. Silk products and the trade of silk have enriched human endeavor through art and culture from ancient times to the latest period of globalization.

a. Sericulture is an eco-friendly agro-based labor-intensive rural cottage industry subsidiary employment and supplementing the income of rural farmers especially the economically weaker section of the society. Sericulture occupies the place of pride in the rural economy. Sericulture can be practiced even with very low land holding. Low gestation, high returns make sericulture an ideal program for weaker section of the society. Sericulture plays very effective role in the utilization of the

natural resources in a most effective manner for socio-economic upliftment with livelihood and employment and income generation. In recent decades, sericulture has become a leader in agriculture development. Today, it is a high-tech, high value farm enterprise providing gainful occupation to around six million persons in rural and semi-urban areas in India. It has become the most visible means for both wealth creation and livelihood improvement.

b. Growing of mulberry is the first and foremost prerequisite for successful sericulture. Mulberry - a hardy, deep rooted perennial plant grows continuously throughout the year under favorable climatic conditions and it is extensively cultivated over a wide range of soils. In one acre of mulberry garden five to six crops can be harvested in an annum and 800-1200 Disease Free Laying's (DFLs) can be reared. Mulberry leaf forms the basic food material for silkworm and bulk of the silk produced in the world comes from mulberry sector. The silkworm requires specific quality of leaves during different phases of its growth and in order to complete larval life cycle (comprising five instars and four moults successfully) as well as to harvest sound cocoon crop and to obtain the quality silk.
c. The silkworm rearing is done either in permanent reinforced ventilated buildings or in the temporary tin roofed sheds with the support of steel or bamboo shelves. These rooms are to be cleaned regularly to maintain hygiene and protect the worms from several microbial infections and pest incidences. Two-acre land for mulberry and silk worm rearing facility for 300-360 DFL per crop season will give a sustainable net income of Rs.3-4 lakh per annum depending on the price of cocoons in the market and value addition to the cocoons.

4.5 APICULTURE

Apiculture is the art of raising the honey bees for the commercial purpose. In Latin the word 'apis' means bee and 'culture' is rearing. Apiculture as an agribusiness activity has following economic importance.

a. Source of honey- a nutritional food to human beings
b. Source of bee wax- having wide industrial applications
c. Honey bees as important pollinating agents in several field crops to improve the productivity of agriculture
d. Agents of ecological stability and sustainability

There are four major species of bee which are of importance in apiculture as an Agri-based enterprise.

a. Apis dorsata/ the rock- bee is the largest honeybee. This is difficult to domesticate because of its stinges. This builds single large open comb on high branches of trees and ceilings of buildings.
b. Apis indica / The Indian bee is the medium - sized hive consisting of several parallel combs in dark places such as cavities of tree trunks and mud walls which can be domesticated.

c. Apis florae / the little bee is the small – sized bees building single small combs in bushes, hedges, etc.
d. Apis mellifera/ The European bee resembles the Indian bee (Apis indica). This has been introduced in many parts of the world including India. It is easily domesticated.

i. To practice apiculture, the farmer must understand the castes of bees. There is one queen, some thousands of sterile males and few drones' functional males. In the hive making, all the caste bees have a specific function of reproduction (queen bee), nectar collection (sterile workers) and mating flights or swarming (drones).

The honey bee rearing for commercial purpose is practiced in either indigenous way or in the modern method of hive keeping. In the traditional or indigenous method, the naturally found honey bee hives are located and the honey is collected in containers and used or marketed for human consumption. Though is not a profit-oriented business, this activity has sustained the livelihood of many tribal population in many countries.

i. In the modern practice of bee keeping, the hives of wooden materials are prepared and kept for artificial rearing of honey bees. The hive will be prepared by assembling different parts like floor, entrance block, brood chamber, queen excluder, super, crown board, super etc. All these are assembled in vertical fashion from the lowest to the top in the order. The wooden frames so arranged are filled with wax sheets on which the combs are built by the bees. The only entrance to the hive is below the large bottom box (brood chamber). The queen is usually confined to the brood chamber. The honey is stored in the top boxes called as supers. The queen is prevented from going to the 'supers' by the 'queen excluder, which allows only the worker bees to move.
ii. Apiculture can be started in the rural areas by all farmers of any land holding size as it is mainly done on bunds or in the boundaries of the fields. Ideally small farmers can keep around 100 hives and earn an income of Rs.1,50,000 to 200,000 per annum if they plan the continuous rearing.

4.6 LET'S SUM UP

The economic, social and ecological indicators are interrelated and influence one another. All three are essential to attain sustainability in agriculture. Any practice or enterprise that degrades the natural resource base, or pollutes the ecology will have no ability to produce consistently. An enterprise that isn't profitable over relatively long time will also terminate at some stage.

The practice that is not in harmony with the people of the society will also lose its sustainability. Therefore, sustainable agriculture must include all three - ecologically sound, economically viable and socially responsible.

The three enterprises discussed above; the mushroom farming, sericulture and apiculture will hold lot of importance to bring sustainability to farming. These miscellaneous Agri-enterprises are assuming greater importance as they are an

additional source of income without competing much for farm resources of the farmers and Agripreneurs and they also contribute in conservation of ecology.

4.7 CHECK YOUR PROGRESS

1. Write the major steps involved in mushroom cultivation?
2. What is the different type of substrata that can be used for spawning mushroom?
3. What are the approaches followed in practicing sericulture?
4. Explain the economic significance of apiculture?

4.8 FURTHER READINGS/ REFERENCES

1. Singh Manjit, Bhuvnesh Vijay, Shwet Kamal and G C Wakchaure, Mushrooms: Cultivation, marketing and consumption, A book by ICAR-Directorate of Mushroom Research, Solan (HP)

2. G Ganga and J Sulochana Chetty, A book on an introduction to sericulture by G Ganga and J Sulochana Chetty. Published by S Chand Publications.