UNIT 2 AGRO-ECOSYSTEMS

Structure

2.1 INTRODUCTION

In the earlier unit you have read about the emergence and development of agriculture through the ages and learnt that agriculture was developed for a simple but fundamental purpose to provide adequate human nutrition. During the last century, modern agriculture became resource intensive and technology based and enabled the green revolution to happen. The apparent success of production agriculture depended on the world's capital held in the form of soil organic matter and nutrients. One unintentional outcome of production oriented agriculture is the recent global degradation of soil and water resources and the consequent loss of biodiversity. Further, expansion of agriculture into the forests and conversion of rangeland into cropland, have aggravated the situation. Agriculture now faces the problem of enhancing food production while simultaneously reversing the resource degradation and overcoming the harmful effects of chemicals used in agriculture. Therefore, it is necessary to view agriculture from an ecosystems perspective. The ecosystems that are used for agriculture are known as **agro-ecosystems.**

Odum (1984) defined agro-ecosystems as domesticated ecosystems that are in many basic ways intermediate between natural ecosystems such as grasslands and forests on one hand and fabricated ecosystems such as cities on the other. Agro-ecosystems are "areas where at least 30% of the land is used as cropland or highly managed pasture." They cover approximately 28% of Earth's land area, excluding Greenland and Antarctica — a total of 4.92 billion hectares. Of this, about 30% is cropland and 70% is pasture. Irrigated agro-ecosystems comprise little more than 5% of the total, but produce about 40% of the world's crops. These systems are also solar powered as are natural ecosystems but differ from them in various aspects.

In this unit we will explain how the concept of agro-ecosystems is used to describe a geographically and functionally coherent domain of agricultural activity. We will also discuss the various living and nonliving components and the interactions among them. The discussions related to the structural and functional components within the agro-ecosystems will provide the background for discussions in further units of this course.

You will also learn about the various agro-climatic zones of the Indian subcontinent and their influence on the productivity of the region.

Objectives

After studying this unit, you should be able to:

- define and differentiate between agro-ecosystems and natural ecosystems;
- describe the various structural and functional components of agro-ecosystems;
- enumerate the various agro-ecosystems; and
- describe the agro-climatic zones and sub-zones of the Indian region.

2.2 CONCEPT OF AGRO-ECOSYSTEMS

The agro-ecosystem is an ecological system modified by humans to produce agricultural products. Ecologically such systems are less complex than natural systems, but are made complex by the imposition of socio-economic values and defined goals.

Natural ecosystems can extend over large areas and make up large systems such as grasslands, mangroves, coral reefs, ponds, oceans, tropical forests etc. However, when farming is practiced then different ecological conditions and new ecosystems known as Agro-Ecosystems are created. Agro-ecosystems are the living communities of soil, plants, and animals that constitute our farms, croplands, orchards, pastures, and rangelands. More than 90% of all the crops and livestock we consume as well as livestock feed is produced by agro-ecosystems. They also contribute fibre crops such as cotton, flax, hemp, and jute, which we use for clothing and textile manufacturing.

The use of an agro-ecosystem approach in agricultural development requires the recognition of the existence of interactions among biological and natural resource variables, and, in all but the very lowest level, of social and economic considerations as well. People are at the centre of agro-ecosystems.

To analyse the productivity or sustainability of any agro-ecosystem requires in theory, a reference to all possible variables and their interactions, a task made possible only by a process through which the major or priority issues and interactions are identified by a community of end users and other participants appropriate to the level of reference.

Agro-ecosystems are conceived as existing in a four dimensional space, the parameters of which are **productivity, sustainability, stability** and **equitability**. The hierarchy of agro-ecosystems is presented in Fig. 2.1

No matter how they came about, our lives depend on agro-ecosystems. For they have kept pace with our demands for food, feed, and fibre over the past 4 decades as the global population doubled. In fact, agro-ecosystems provide, on average, 24% more food per person today than they did in 1961. But by 2020 agro-ecosystems will have to supply food for an estimated 1.7 billion more people.

Spatially an agro-ecosystem could vary from a system involving a crop or a farm to communities and watershed composed of many farms and even large eco-regions. Regardless of the scale, agro-ecosystems are characterized by driving variables (solar radiation, rain, water and wind), inputs such as immigration, inflow of capital, information, energy, fertilizers, chemicals and human infrastructure and knowledge. Most agro-ecosystems experience losses and outputs in the form of export of crops and livestock, loss of nutrients, water and emigration.

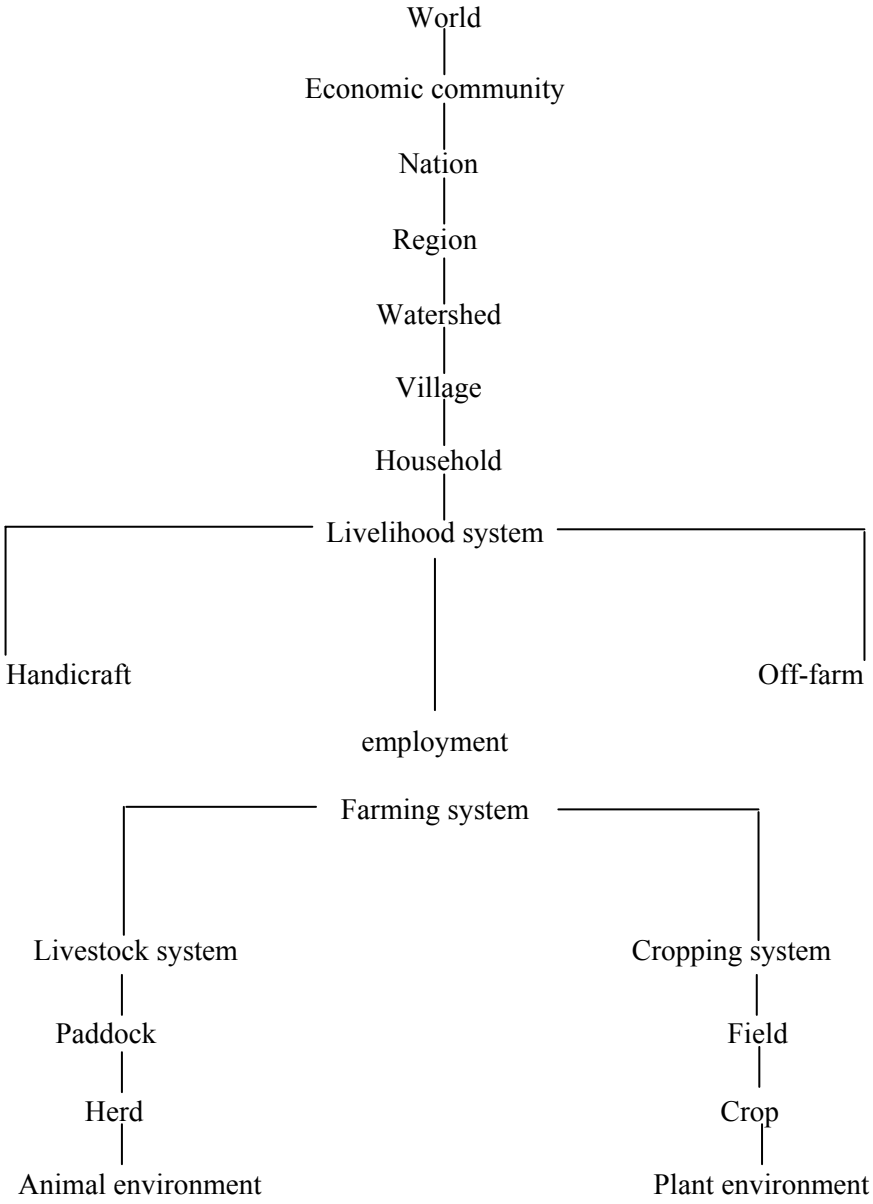


Fig.2.1: The hierarchy of agro-ecosystems (Conway, 1987)

Some of the most important goods and services provided by agro-ecosystems are given in the table below:

Table 2.1: Goods and services provided by agro-ecosystems

Goods	Services
Food – Agro-ecosystems provided 94% of all the plant and animal protein and 99% of all the calories humans consumed in 1997.	**Employment** – Food production employs approx. 1.3 billion people and is valued at around $1.3 trillion per year.
Meat – Global meat demand grew 2.9% per year between 1982 and 1994 and is expected to increase 58% by 2025, increasing people's protein intake.	**Carbon storage** – Agro-ecosystems contain 18-24% of the carbon stored in all terrestrial ecosystems, mostly in the soil rather than the plants.
Fibre – Fibre crops in North America comprised 0.1% of harvest area and about 0.03% of the total value of agricultural production.	**Biodiversity** – Although 90% of our calorie intake comes from just 30 crops, more than 7,000 crop species exist—a wealth of alternative food crops.

2.2.1 Agro-ecosystems versus Natural Ecosystems

Agro-ecosystems are distinct from unmanaged natural ecosystems as they are intentionally altered and often intensively managed for the purpose of providing food, fodder, fibre and other products, Hence they inherently have human community, economic and environmental dimensions (Fig. 2.2).

Fig.2.2: Agro-ecosystems differ from natural ecosystems

Agro-ecosystems can be distinguished from natural ecosystems on the following counts:

- In agro-ecosystems we try to stop ecological succession so that the ecological system is kept constant. Most crops are early successional species, which means that they grow best when sunlight, water, chemical inputs are abundant. Therefore, agro-ecosystems are intensively manipulated by humans through ploughing, tillage, mowing, irrigation, treatment with pesticides, fertilizers, etc.
- The auxiliary energy sources that enhance productivity are processed fuels along with human and animal labour rather than natural energy.
- In natural ecosystems, plants get nutrients from natural cycling of minerals. The leaves of plants and dead bodies of herbivores and carnivores get decomposed and release nutrients into the soil, which are then absorbed by the plants. In agro-ecosystems farmers apply farmyard manure and inorganic fertilizers such as nitrogen, potassium and phosphorus, which augment the natural mineral cycles.

- In agro-ecosystems high yielding varieties are grown with application of fertilizers and extensive irrigation for getting higher production. Pesticides protect these. Crop varieties with inherent resistance to pests and diseases are bred through genetic selection. Thus genetic selection replaces natural selection.

- Diversity is greatly reduced by human management in order to maximize yield of specific food or other projects. Crops are planted in neat rows. In most natural ecosystems many species of plants grow mixed together in complex patterns. Therefore, pests and disease affect agro-ecosystems more easily.

- Food chains are generally simplified in agro-ecosystems. Pest control reduces the abundance and diversity of natural predator species and parasites of crop plants. This way species that could compete with crops for nutrition are eliminated. Thus agro-ecosystems have less species diversity than natural ecosystems making them more susceptible to undesirable changes.

- Control is external and goal oriented rather than internal control via subsystem feedback as in natural ecosystems.

- Ploughing and tilling disturb the natural formation of soil and expose it to erosion. Nothing in nature resembles the ploughing process, which turns over the soil to a specific depth.

- In natural ecosystems there is a natural dispersal of seeds from the plants. The new plants get established wherever they fall. In agro-ecosystems, natural seed dispersal is replaced by manual or mechanized sowing of seeds after ploughing the land.

2.2.2 Types of Agro-ecosystems

The broad divisions of agro-ecosystems are based on the types of crops cultivated or animals tamed. Some of the types of agro-ecosystems commonly found are:

- **Seasonally Cropped Systems**: The crops and plants that complete their life cycle in a single season are part of seasonally cropped agro-ecosystems. Most of the agro-eco systems in the world are cultivated with seasonal crops such as cereals, pulses, and oilseeds which fulfill the food requirements of the people. Soil is degraded more in seasonally cropped areas due to tillage operations. Soil fertility is lessened since in each season a new crop is to be sown, and the extent of nutrient depletion/erosion depends on the nature of the crop.

- **Permanently Cropped Systems**: Large tracts of land are under perennial cropping system such as orchards, plantation crops like cardamom, rubber, coconut, areca nut, cashew nut, oil palm etc. In this type of agro-ecosystems it is also possible to grow seasonal crops in the inter row spaces.

- **Forestry Systems**: All manmade forests are part of the agro-ecosystem. In some forests perennial grasses are grown for fodder purposes or for grazing of cattle. Man made forests are classified into (i) agro forestry which is forestry on farmed or cropped land; (ii) social forestry which means raising and management of forests outside the traditional forest area for meeting the basic requirements of the people, environment amelioration and rural development; (iii) government forest plantation.

- **Aquaculture Systems**: Manmade water bodies used for fish culture and cultivation of aquatic plants.

- **Integrated agro-ecosystems**: consisting of a suitable mixture of various farming components viz. cropping systems, livestock rearing, horticulture, aquaculture, poultry etc. (You will read more about integrated farming systems in Unit 12 of this course).

Box 2.1: Agricultural extent and land use changes in South Asia

- Total land area under agriculture – 73%
- Intensive agricultural use – 70%
- Crop based agro-ecosystems – 91%
- Share of global irrigated land area – 35%
- Annual harvested area as a proportion of total cropland or cropping intensity – 1.1% (average cropping intensity globally is 0.8%)

SAQ 1

Define an agro-ecosystem. Give two main differences between agro-ecosystems and natural systems.

2.3 COMPONENTS AND INTERACTIONS OF AN AGRO-ECOSYSTEM

Like any other natural ecosystem, agro-ecosystems may also be described as open systems that receive **inputs** from outside and lose energy and matter as **outputs.** The major outputs are primary and secondary production (plant and animal production) and nutrient elements. Internally, the system comprises a number of interrelated components through which energy and matter flow (Fig. 2.3).

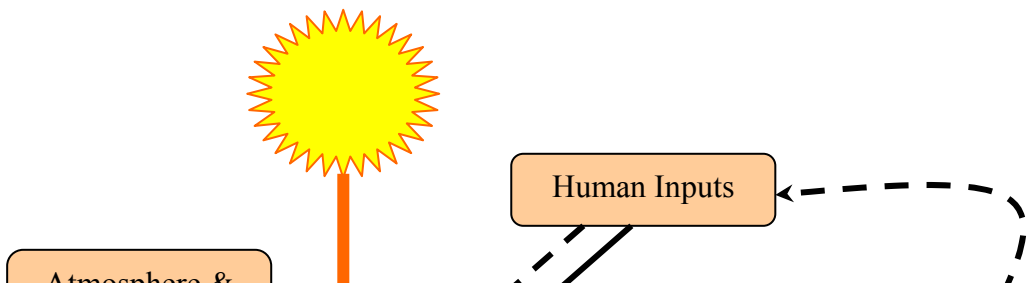
Like natural ecosystems, agro-ecosystems can be thought of as including the processes of primary production, consumption, and decomposition interacting with abiotic environmental components and resulting in energy flow and nutrient cycling. Economic, social, and environmental factors must be added to this primary concept because of the human element that is so closely involved with agro-ecosystem creation and maintenance.

Inputs into the system occur in a number of ways– by weathering of rocks to provide nutrient elements and soil particles; by solar radiation to provide energy; by precipitation to provide water and nutrient elements; by transfer from nearby land surfaces that provide water, solids and nutrient elements (through erosion or runoff) and above all through the inputs provided by the farmers. These inputs by the farmers include seeds, fertilizers, manures, livestock, animal feeds, pesticides and fuel energy.

Through various inputs, human beings have been able to control the agro-ecosystems and maintain their capacity for high levels of outputs that characterize the modern agricultural systems. In the following subsections we will discuss the structural and functional attributes of the agro-ecosystem.

2.3.1 Structure of Agro-ecosystems

In order to understand the structure of agro-ecosystems we must understand the first principle of ecology that all things are interconnected and based on the relationships among the biotic (living) communities and the abiotic environment. Like natural ecosystems, the structure of agro-ecosystems is made up of biotic and abiotic components present at a particular place.



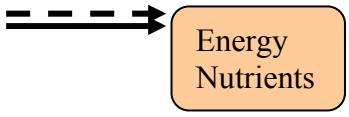


Fig.2.3: The general structure of an agro-ecosystem showing its components and relationship with external factors.

Biotic components

The biotic components of the system are the crop plants, animals and the microorganisms present in the soil. Crops and weeds are the primary producers while the secondary producers are the herbivores comprising insects, birds and small mammals. The decomposers are mostly species of fungi, microorganisms and nematodes etc.

Crop plants: Of the numerous species of plants, only about 7000 have been tried as agricultural crops and only150 species have been cultivated on a large scale. Some crops provide food; others provide fodder, and other commercial products including oil, drugs, pesticides and fibres. The world's food production is provided by only 14 crop species –wheat, rice, maize, potatoes, sweet potatoes, manioc, sugarcane, sugar beet, common beans, soybeans, barley, sorghum, coconut, and bananas. Of these, six species provide directly or indirectly 80% of the total calories consumed by human beings. Overall globally crops occupy 31% of agricultural areas and the remaining area is occupied by pasture and this varies region wise. In South Asia, 91% of the cropland is under annual crops such as wheat, rice and soybean, while perennial crops such as coffee, tea, fruits, sugarcane occupy the remainder. Though crops are maintained as pure populations, weeds grow along with the crops despite best efforts to control them, by adjusting their life cycle within the interim period of inter-cultural operations. Weeds enter into competition with crop plants for necessary growth requirements and reduce the growth and yield of the crops. The density, frequency and vigour of the crop system are useful in understanding the relationships between the crops-weed- insect- bird in the agro-ecosystem. Biomass is a good indicator of community structure and unlike natural communities the biomass of crops steadily increases from early vegetative stage till harvest. A study of the leaf area index, amount of chlorophyll distributed in the stem, leaves etc., biomass profile and energy storage patterns of the primary producers provide information about their activity zones.

The chlorophyll pigment in the green plants traps light energy, and synthesizes carbohydrates using carbon dioxide and water in the photosynthesis process. Chlorophyll content is correlated with dry matter production and used as an index of productive potential of the plant population. Chlorophyll content varies with different crop plants as well as between different varieties of the same crop. It increases with age and declines after flowering due to senescence and shedding of lower leaves. Their leaf area measures photosynthetic size of plants and the most appropriate measure of leaf area for field crops is the leaf area index, that is, the leaf area per unit area of land. In crop plant communities, the average value of leaf area index is 2-6, while in natural communities, the leaf area index may be as high as 6-13 for forests, and 3-15 for grasses. In annual crops, the leaf area index increases with age and starts to decline after flowering. Leaf area index is positively correlated with productivity and maximum net production is obtained when it is approximately 4.

Energy content of the crop plants is an indicator of the structure of the producer subsystem. Energy content varies with the age and chemical content of the plants. In certain paddy varieties, high energy content during early vegetative period has been reported. Of the total energy locked up in biomass, 85 to 90 percent is harvested by human beings as grain and fodder, while the remaining 10-15 percent is left as stump and roots and is available to heterotrophs in the soil.

Consumers: The homogenous plantation of crops in the fields permits very few animals to live and thrive in the agro-ecosystem. The crop plants provide shelter, site for nesting, protection from enemies and predators. Food chains in agro-ecosystems are simple with only 2 or 3 trophic levels. Activities like ploughing and tilling the soil disturb it to quite an extent, often changing the micro flora and fauna completely so that entirely new conditions are created. Also the crop communities provide scant shelter to mammals and only small mammals make temporary visits. For example, a study in Varanasi showed that in a maize crop ecosystem, insects and bugs were the main consumers. Some birds were found to come picking the insects of the farm and these were only temporary visitors so it was not possible to ascertain whether they were preyed upon by other consumers.

Decomposers: Decomposer activity is generally less in agro-ecosystems due to tillage in crop fields, application of chemical fertilizers, pesticides, herbicides and lack of organic matter in the soil. The soil is full of microorganisms such as bacteria, actinomycetes, fungi, algae, viruses and protozoa. Bacteria and actinomycetes are the most numerous of microbial groups present in the soil. Microbes impact the agro-ecosystem in a number of ways:

- Decomposition of organic matter with release of nutrients,
- Formation of beneficial soil humus by decomposing organic residue and through formation of new compounds,
- Release of plant nutrients from insoluble inorganic forms,
- By formation of mycorrhizal associations,
- Transformation of atmospheric nitrogen to plant available N,
- Improvement of soil aggregations, aeration and water infiltration, and
- Antagonistic action against insects, plant pathogens and weeds.

Abiotic Components

Abiotic components of the agro-ecosystem are soil, inorganic nutrients, climate, water, atmosphere and solar radiation.

Soil acts as a nutrient pool and forms the environment of the roots and microorganisms. Soil in agro-ecosystems is oversimplified because the upper layers are disturbed due to farming practices and extra inputs of energy and matter by the farmers in the form of manure fertilizers, fossil fuels and water. Often extra salts are leached due to water logging and irrigation patterns. The soils are generally poor in organic matter content as the crops are harvested and removed to be used as food and fodder

2.3.2 Processes and Functions

Neither the agro-ecosystem nor its biotic components can exist without the constant supply of energy to maintain the biotic structures and their functions. The source in all cases is the sun, which drives the carbon and energy fixation in green plants. Trophic processes are the essence of ecosystem functioning for through them solar energy passes to the animals and other heterotrophs and allows them to exist. The ultimate limit on the growth of crops in the agro-ecosystem is determined by the energy flow through the system. To understand the actual and maximum possible production of organic matter in the agricultural system we must understand the basic concept of energy flow.

The total amount of organic matter in a particular ecosystem is called its biomass which includes all the living things and all the products of living things. Biomass is increased through biological production and this change over a period of time is known as net productivity.

Productivity is the quantity of product or output from the agro-ecosystem per unit of some specified input. Organic productivity that is from plants or livestock is driven by photosynthesis that uses the light energy. Crop plants during peak season can convert 6-8 % of total daily solar energy into organic matter in gross production.Net production averages about half the gross production. Therefore, only 50% of the energy retained in the plant body as net production is available to heterotrophs including humans and their cattle. The crop efficiency relationship between energy input (in terms of solar energy) and energy output (carbohydrate productivity) has been given in Table 2.2.

Table 2.2: Relationship between solar radiation and gross and net production (kcal/m^2/day)

Crop	Solar Radiation	Gross Production	Net Production
Sugar cane	4000	306	190
Maize	6000	405	190
Sugar beet	2650	202	144
Wheat	1567	55	43
Paddy	2904	–	60

In addition to the major inputs of solar energy, modern agriculture has substantial inputs in the form of fertilizers and pesticides. The energy input can be assessed in terms of energy necessary to produce them and in terms of energy necessary to apply it to the soil or crop. The energy cycles in most agro-ecosystems are inefficient in that only a small proportion of the total energy input is available to human beings through food. But the higher net production of the agro-ecosystem is attributed to the extra input of energy of fossil fuels, humans and their animals as well as materials such as fertilizers and water, genetic improvement of crop plants and pest control methods.

Energy flow is the movement of energy through the ecosystem− from the external environment through a series of organisms, back to the environment. In cropland, every effort is made to provide optimum conditions to producers to keep their efficiency at the maximum limit. In annual crops this happens for a short period of about 60-90 days, after which the producer subsystem reaches maturity and photosynthesis decreases due to aging. After harvesting of crops, 85-90% of energy accumulated by the above ground compartment of cereals enters into a simple grazing food chain consisting of humans and cattle.

Energy entering the detritus food chain of cropland agro-ecosystem amounts to about 5-15% of net production. The stubble, dead leaves, and litter fallen on the ground along with the roots inside the soil are sources of chemical energy input into the soil

subsystem. This is not sufficient and therefore, a large amount of extra material is added to the soil with each crop. A flow chart showing the energy flow in an Indian agro-ecosystem is given in Fig. 2.4.

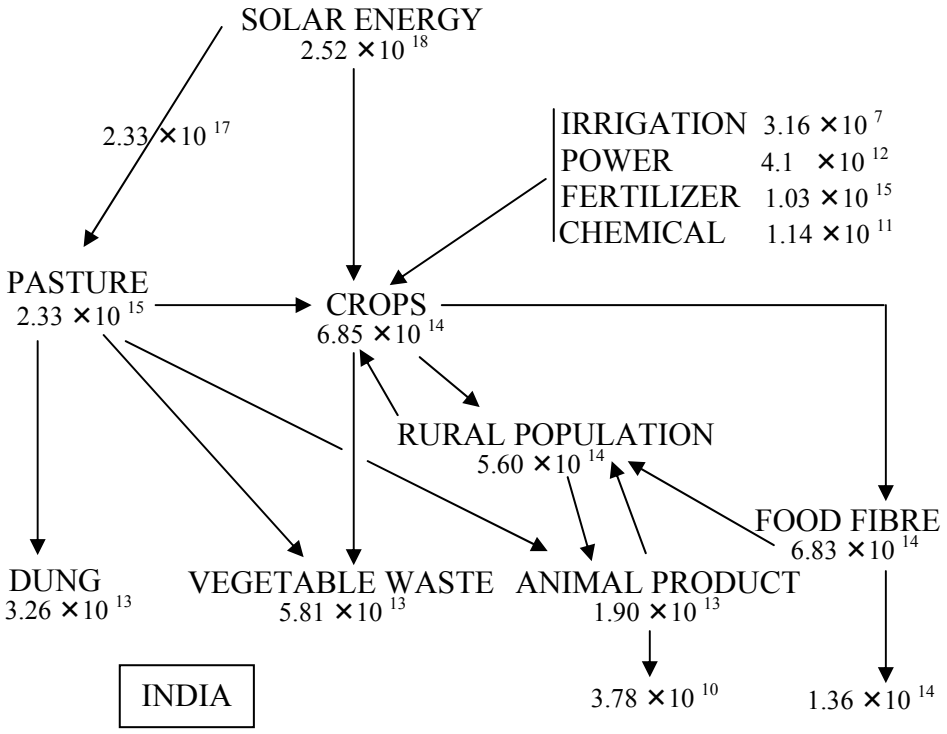


Fig.2.4: Energy flow in Indian agriculture, all values are in kcal per year.

The energy flows in Fig. 2.4 are based on a variety of sources and assumptions. Insolation was assumed to be 10^{10} kcal ha^{-1} yr^{-1}. Two other assumptions were made: (1) Pasture crop is one percent of incident energy and (2) 10 cal of food are required for one calorie of animal product. It is also assumed that half of the animal feed is from pasturage. The maximum estimate for the energy cropped from pasture would be the sum of kilocalories in dung, vegetable waste and animal products. The arrow from pasture to crop is the energy of bullocks used in cultivation.

Nutrient cycling: In terrestrial ecosystems the soil acts as a source of nutrient elements for the plant. In natural ecosystems the nutrient levels are maintained by biogeochemical cycling process. In agro-ecosystems natural processes do not replenish the nutrient loss. The huge inputs of fertilizers and other inputs into the system make the nutrient cycles imperfect or acyclic. Fig. 2.5 shows the cycling of nutrients in an agro ecosystem.

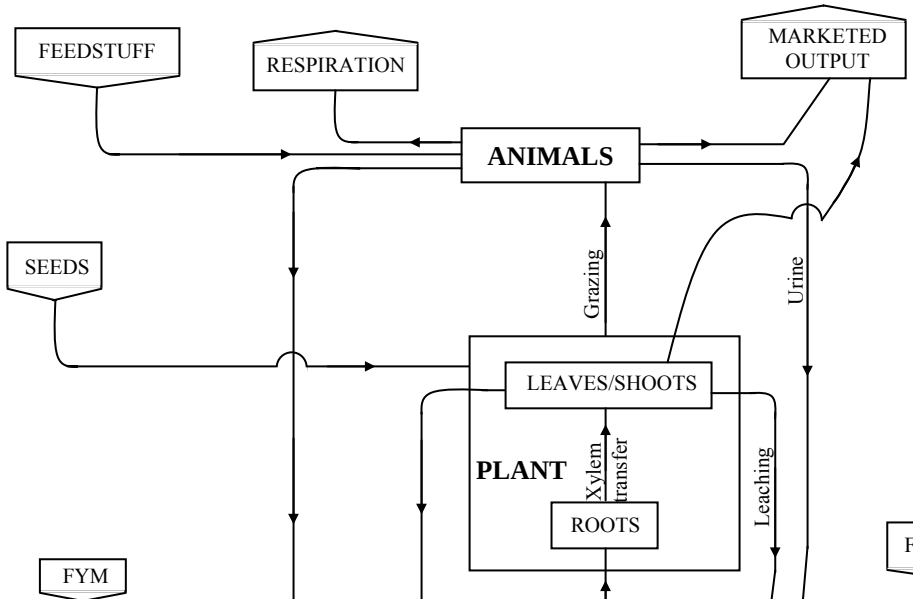


Fig.2.5: Nutrient cycles in agro-ecosystem (FYM = Farmyard manure). The three main pools or reservoirs are crop plants, livestock and soil

Hydrological cycling: As we all know water plays a crucial role in all agro-ecosystems. It is essential for maintaining turgor in plants and transporting nutrient elements to and through the plants. Water also has a vital role in leaching erosion and weathering of rocks. The main input of water into the system is through rainfall and where this input is insufficient, irrigation makes up for it. The main losses are due to evapo-transpiration, drainage to ground water and lateral flow to streams. Storage of water occurs in soil, plant tissue and livestock. Fluctuations in water quantity have a considerable influence on the growth of crops.

SAQ 2

What are the basic components of agro-ecosystems?

2.3.3 Factors Affecting the Structure and Functions

Some of the factors affecting the structure and functioning of agro-ecosystem are inter and intra specific competition, agricultural practices such as ploughing, shifting agriculture, crop rotation, stubble burning, inorganic fertilizers, irrigation, pests and disease control, introduction of high yielding varieties. Besides these, climate and edaphic factors like drought, frost, day length, soil chemical properties affect the structure and functions of the agro-ecosystems.

Competition: Plant competition is density induced. In a crop land the primary producer is of the same life form and draws its life requirement from the same resource. Competition affects the community structure and changes the rate of transfer of nutrients by affecting the efficiency of the interacting individuals. Often plants show adaptations that enable them to use the environmental resources more efficiently. In the competition for light and carbon dioxide, canopy structure and photosynthetic area are important. While for water and nutrient competition, root activity and uptake capacity are important. In cultivated fields, inter-specific competition occurs between plants and weeds. If the plants are not weeded in time then severe damage to the crop will be the result. Usually the competition occurs at an early vegetative stage; once the crop is established, the weed is suppressed.

Climate: The determinants of climate, solar radiation, temperature, humidity, rainfall and wind show cyclic changes during the year, thus forming a characteristic pattern of the climate. All activities of the plant from seed germination to seed formation are influenced by climatic conditions. Since crop plants have a narrow tolerance range of environmental factors they are affected by slightest changes in climate. For instance, it was seen from an experiment that when a high yielding paddy variety was sown in winter instead of the rainy season then in spite of all the external inputs like fertilizers, irrigation etc., it showed poor growth.

Ploughing: The field has to be prepared for each crop in the agro-ecosystem. Ploughing turns up the soil up to 30cm depth. This makes the top soil loose and vulnerable to erosion. The physical properties of soil are completely changed and the micro flora and fauna of the soil are affected, which has an impact on the structure and functioning of the system. Some times, the dormant weed seeds are exposed and cause severe problems.

Shifting Cultivation and Crop Rotation: Through shifting cultivation, large scale changes have been brought about in the vegetation patterns especially in the ecosystems along hills and in savannahs. Introduction of weeds and exotic species and biotic components of the abandoned agro-ecosystem results in completely changed community structure. The practice of crop rotation keeps the soil of agro-ecosystems healthy. In well drained soils, practices such as rotation of wheat, maize and legume and occasional green manuring of crop fields maintain the soil fertility and enhance its microbial population.

Fertilizers: Organic fertilizers (cow dung, compost and manure) have been used in traditional farming. These improve the physiochemical properties along with increase of microorganism population. The present day agro-ecosystems require chemical fertilizers to sustain the increased yields. Too much of these fertilizers cause salinization, the microbial density decreases and ultimately fertility gets reduced.

Irrigation: The use of chemical fertilizers and intensive cropping require increased irrigation. Only 17% of agro-ecosystems depend on irrigation. Irrigation without adequate drainage causes the raising of water table and water logging of soil; salts are lifted to the surface of soil, making the land infertile.

Introduction of high yielding varieties: New high yielding varieties of crops (HYV) that have different environmental requirements have been introduced in the agro-ecosystems. They pose several ecological problems like water, nutrient and pesticides requirement and affect soil biodiversity.

Pests and Weeds: Pests are small mammals, insects, fungi, bacteria, etc. that destroy the crop plants in modern agro-ecosystems. Almost 99% of the potential pests are checked by natural enemies and not by human intervention, and by physical features such as temperature, moisture, and availability of breeding site.

As discussed earlier, weeds are competitors of crop plants for nutrient requirements. Therefore, pest and weed control programmes attain top priority in managed agricultural systems. Pests and weeds are controlled manually or through application of pesticides and herbicides. Large-scale use of these has been responsible for extensive environmental damage. (You will read about this in the next unit.)

Pests and weeds can also be regulated by biological control methods. When introduced under natural conditions, certain organisms affect certain harmful insects and plants without affecting the biological processes of the system. Bacteria, fungi, insects and other animals like fish and birds have been tried as possible agents of biological control.

SAQ 3

How does the climate of a place affect the agro-ecosystem? Name two other factors that affect the agro-ecosystem structure the most.

2.4 AGRO-CLIMATIC ZONES

Since agriculture is highly location-specific, grouping the available land area in a region or country into different agro-ecological regions based on certain identifiable characteristics becomes important. **An ecological region is an area of the earth's surface characterized by distinct ecological responses to macro-climate, as expressed by soils, vegetation, fauna, and aquatic systems (FAO, 1983).** This would help the region to engage in more rational planning and optimizing resource use for the present and in preserving them for the future. With the 329 million hectares of the geographical area, India presents a large number of complex agro-climatic situations. Crop yield depends on many factors like weather, soil type and its nutrient status, management practices and other inputs. Of these, weather is a very important aspect, efficient crop planning, therefore, requires proper understanding of agro-climatic conditions in a region/country.

An agro-climatic zone is a land unit in terms of major climates, suitable for a certain range of crops and cultivars. Several attempts have been made to delineate major agro-ecological regions in respect to soils, climate, physiography (physical and geographical features) and natural vegetation. We present the some of the important agro-ecological and agro-climatic divisions of the Indian Subcontinent:

A) Agro-ecological regions by the ICAR (Indian Council of Agricultural Research).

B) Agro-climatic regions by the Planning Commission.

C) Agro-climatic zones under NARP (National Agricultural Research Project).

D) Agro-ecological regions by the NBSS & LUP (National Bureau of Soil Survey and Land Use Planning).

A) Agro-ecological regions by the ICAR

In 1973, ICAR identified eight major agro-ecological regions in India for more meaningful planning of agricultural research and development. These divisions are:

1. Humid Western Himalayan Region
2. Humid Bengal - Assam Basin
3. Humid Eastern Himalayan Region and Bay Islands
4. Sub-humid Sutlej-Ganga Alluvial Plains
5. Sub-humid to Humid Eastern and South-eastern Uplands
6. Arid Western Plains
7. Semi-arid Lava Plateau and Central Highlands
8. Humid to Semi-arid Western Ghats and Karnataka Plateau

These regions consist of large geographical area of land having major groups of geological formations, physiography, climate, soils, vegetation, land use and cropping patterns. Some of the essential features of these regions are described here.

1. **Humid Western Himalayan Region**: It consists of Jammu and Kashmir, Himachal Pradesh and hill division of Uttar Pradesh, namely, Kumaon and Uttaranchal. High mountains and narrow valleys characterize it. The climate varies from hot and sub-humid tropical in the South to temperate cold arid in the North, with the rainfall ranging from 8 cm in Ladakh to over 100 cm in Jammu area. It has sandy loam mountain meadow, loamy and acidic sub-montane and loamy brown hill soils. Nearly half of the area is under forest, and horticulture including sericulture supplements agriculture. Rich forest wealth and rangelands are the assets of this region. Degradation of forests is the major problem.

2. **Humid Bengal-Assam Basin**: It covers West Bengal and Assam representing the Ganga-Brahmaputra alluvial plain. It is characterized by semi-stabilized sand dunes on alluvial terraces, lateritic remnants in the West, and numerous creeks and swamps in the deltaic tract. It experiences hot humid monsoonal climate, and the rainfall ranges from 220 to 400 cm. The predominant soil groups are alluvial, red and brown hill. Rich forests in Assam and fertile deltas in West Bengal are the assets. Frequent floods in Assam and extensive occurrence of saline patches in the deltaic tracts are the major constraints.

3. **Humid Eastern Himalayan Region and Bay Islands**: It includes Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, and Andaman & Nicobar Islands. It consists of the Eastern Himalayan and the Arakan Ranges with a wide range of elevation. The rainfall ranges from 200 to 400 cm. The major soil groups are brown hill, red and yellow, alluvial, and acidic laterites. It is endowed with rich evergreen forests. Animal husbandry and pisciculture have great potential. Major liability is shifting cultivation leading to deforestation and soil erosion.

4. **Sub-humid Sutlej-Ganga Alluvial Plains**: It comprises Punjab, plains of Uttar Pradesh, Delhi, and Bihar. The entire region is level, except for the Tarai-Bhabar tract. It experiences extremes of climate, with very hot summer and very cold winter. The rainfall ranges from 30 to 200 cm. The major soil groups are calcareous sierozem, reddish chestnut, alluvial, and patches of saline and alkali soils. The soils are highly disturbed in Bihar due to frequent floods. Major area is under cultivation. Generally, the region is double cropped. Flooding, salinity, alkalinity, and erosion are the major problems.

5. **Sub-humid to Humid Eastern and South-eastern Uplands**: It encompasses Orissa, Andhra Pradesh and the Raipur Division of Chhattisgarh. It is characterized by undulating topography, denuded hills, plateau, river valleys, and high lands. The climate is tropical monsoonal, and sub-humid to humid from West to East. The rainfall ranges from 100 to 180 cm. Major soil groups are mixed black, red and yellow, red sandy, laterite, black, and alluvial soils. Rich forest wealth is an asset, and shifting cultivation, soil salinity and acidity are the major constraints.

6. **Arid Western Plains**: It includes Haryana, Rajasthan, Gujarat, and Dadra & Nagar Haveli. It is characterized by extensive alluvial plain dotted with sand dunes, saline depressions and granite hills. The rainfall is scanty, ranging from 10 to 65 cm and erratic. Major soil groups are alluvial, black, desert, saline and alkaline. Nearly one-third of the area is under cultivation. Frequent dry spells, salinity and alkalinity are the major problems.

7. **Semi-arid Lava Plateau and Central Highlands**: It covers Maharashtra, Goa, Daman & Diu, and Western and Central Madhya Pradesh. It is predominantly a plateau region. The climate is semi-arid with extremes of temperature, and the rainfall ranges from 70 to 125 cm except in the Western Ghats where it varies from 330 to 750 cm. Major soil groups are alluvial, black, laterite, mixed red and black, and yellowish brown. More than half of the area is cultivated. Frequent drought is the major problem in the region.

8. **Humid to Semi-arid Western Ghats and Karnataka Plateau**: It consists of Karnataka, Tamil Nadu, Kerala, Pondicherry, and Lakshadweep Islands. The physiographic features are Western Ghats, plateau, river valleys, undulating rocky plains, and coastal plains. The western ghats is humid and the rest of the area is semi-arid. The rainfall ranges from 60 to 300 cm. Major soil groups are black, red, lateritic, and alluvial. Rich forest wealth and Western Ghats suitable for plantation crops are the main assets. Dry farming is prevalent and a considerable area is irrigated through wells, tanks and rivers. Salinity, alkalinity, erosion, and acidity are the major problems.

B) Agro-climatic regions by the Planning Commission

The Planning Commission, as a result of the mid-term appraisal of the planning targets of the Seventh Plan, has divided the country into fifteen broad agro-climatic zones based on physiography, soils, geological formation, climate, cropping patterns, and development of irrigation and mineral resources for broad agricultural planning and developing future strategies. These include:

1. Western Himalayan Region
2. Eastern Himalayan Region
3. Lower Gangetic Plains Region
4. Middle Gangetic Plains Region
5. Upper Gangetic Plains Region
6. Trans-Gangetic Plains Region
7. Eastern Plateau & Hills Region
8. Central Plateau & Hills Region
9. Western Plateau & Hills Region
10. Southern Plateau & Hills Region
11. East Coast Plains & Hills Region
12. West Coast Plains & Ghats Region
13. Gujarat Plains & Hills Region
14. Western Dry Region
15. The Islands Region

C) Agro-climatic zones under NARP

The country has been divided into 131 agro-climatic zones, under the World Bank supported National Agricultural Research Project (NARP) of the ICAR, essentially based on climate, soils, and existing cropping patterns of each State as a unit. The zones identified are:

Code No.	State & Agro-climatic Zone	Zonal Centre
	Andhra Pradesh	
001	Krishna Godavari Zone	-Lam (Guntur)
002	North Coastal Zone	-Anakapalle
003	Southern Zone	-Tirupati
004	Northern Telengana Zone	-Jagityal
005	Scarce Rainfall Zone of Rayalaseema	-Nadyal
006	Southern Telegana Zone	-Palem
007	High Altitude and Tribal Zone	-Rastakuntabai/ Chintapalli
	Assam	
008	North Bank Plain Zone	-North Lakhimpur
009	Upper Brahmaputra Valley Zone	-Tatabar
010	Central Brahmaputra Valley Zone	-Shillongani
011	Lower Brahmaputra Valley Zone	-Gossaingaon
012	Barak Valley Zone	-Karmganj
013	Hill Zone	-Diphu
	Bihar	
014	North West Alluvial	-Pusa/ Madhopur
015	North East Alluvial Plain Zone	-Purnea/Katihar/Agwanpur
016	South Alluvial Plain Zone	-Sabour
	Jharkhand	
017	Central and North Eastern Plateau Zone	-Dumka
018	Western Plateau Zone	-Chianki
019	South Eastern Plateau Zone	-Chatshila/Darisai
	Gujarat	
020	South Gujarat Heavy Rainfall Zone	-Navsari
021	South Gujarat Zone	-Baruch/ Surat
022	Middle Gujarat Zone	-Anand
023	North Gujarat Zone	-Dantiwada
024	North West Zone	-Bhachau
025	North Saurashtra Zone	-Targhadia
026	South Saurashtra Zone	-Junagadh
027	Bhal and Coastal Zone	-Arnej
	Haryana	
028	Eastern Zone	-Karnal
029	Western Zone	-Bawal/ Hissar
	Himachal Pradesh	
030	Sub-mountane and Low hills sub tropical Zone	-Dhaulakuan
031	Mild-Hills sub-humid zone	-Bajaura
032	High Hills Temperate Wet Zone	-Mashobra
033	High Hills Temperate Dry Zone	-Kukumseri

	Jammu & Kashmir	
034	Low attitude Sub-tropical Zone	-R.S. Pora
035	Mid to high altitude Intermediate Zone	-Rajori
036	Valley Temperate Zone	
037	Mid to high altitude Temperate Zone	-Kludwani
038	Cold-arid Zone	-Leh
	Karnataka	
039	North East Transition Zone	-Bidar
040	North East Dry Zone	-Raichur
041	Northern Dry Zone	-Bijapur
042	Central Dry Zone	-Sirsa/ Bidaramana gudi
043	Eastern Dry Zone	-Hebbal/ Chintamani
044	Southern Dry Zone	-Nagamangala
045	Southern Transition Zone	-Navile/ Shimoga
046	Northern Transition Zone	-Dharwar/ Hanumanmatti
047	Hill Zone	-Mudigere
048	Coastal Zone	-Brahmavar
	Kerala	
049	Northern Zone	-Pilicode
050	Southern Zone	-Vellayani
051	Central Zone	-Pattambi
052	High Altitude Zone	-Ambalavayal
053	Problem Areas Zone	-Kumerakom
	a) Onattukara zone	-Onattukara
	b) Kuttanadu Kole zone	-Kuttanadu
	c) Pokkali zone	-Kuttanadu
	d) Low rainfall zone	-Kumarakam
	Madhya Pradesh / Chhatisgarh	
054	Chhatisgarh Plane Zone including Balagharh Distt.	-Raipur
055	Bastar Plateau Zone	-Jagadalpur
056	North Hill Zone Chhatisgarh	-Ambikapur
057	Kymore Plateau and Satpura Hill Zone	-Jabalpur
058	Vindhya Plateau Zone	-Sehor
059	Central Narmada Valley Zone	-Powarkhera
060	Gird Zone	-Morena
061	Bundelkhand Zone	-Tikamgarh
062	Satpura Plateau Zone	-Chindwara
063	Malwa Plateau Zone	-Indore
064	Nimar Valley Zone	-Khargone
065	Jhabua Hills Zone	-Jhabua
	Maharashtra	
066	South Konkan Coastal Zone	-Vengurla
067	North Konkan Coastal Zone	-Karjat
068	Western Ghat Zone	-Igatpuri
069	Sub-mountane Zone	-Kolhapur
070	Western Maharashtra Plain Zone	-Pune
071	Scarcity Zone	-Sholpur
072	Central Maharashtra Plateau Zone	-Aurangabad
073	Central Vidharbha Zone	-Yavatmal
074	Eastern VIdharba Zone	-Sindhewahi

	Orissa	
075	North Western Plateau Zone	-Kerai
076	North Central Plateau Zone	-Keonjhar
077	North Eastern Coastal Plain Zone	-Ranital
078	East and South Eastern Coastal Zone	-Bhubaneshwar
079	North Eastern Ghat Zone	-G. Udayagiri
080	Eastern Ghat Highland Zone	-Semiligulda
081	South Eastern Ghat Zone	-Jeypore
082	South Western Undulating Zone	-Bhawanipatna
083	West Central Table Land Zone	-Chiplima
084	Mid-Central Table Land Zone	-Mahispat
	Punjab	
085	Sub-mountane Undulating Zone	-Kandi
086	Undulating Plain Zone	-Gurdaspur
087	Central Plain Zone	-Ludhiana
088	Western Plain Zone	-Faridkot
089	Western Zone	-Bhatinda
	Rajasthan	
090	Arid Western Plain Zone	-Jodhpur/ Mandore
091	Irrigated North Western Plain Zone	-Sriganganagar
092	Transitional Plain Zone of Inland Drainage Fatehpur	-Sikar
093	Transitional Plain Zone of Luni Basin	-Sumerpur/ Jalore
094	Semi Arid Eastern Main Zone	- Durgapura (Japur)
095	Flood Prone Eastern Plane Zone	-Navgaon (Alwar)
096	Sub-humid Southern Plain and Aravalli Hill Zone	-Udaipur
097	Southern Humid Plain Zone	-Banswara
098	South Eastern Humid Plain Zone	-Kota
	Tamil Nadu	
099	North Eastern Zone	-Vridhachalam
100	North Western Zone	-Paiyuar
101	Western Zone	-Coimbatore/ Bhawani Sagar
102	Cauvery Delta Zone	-Aduthurai
103	Southern Zone	-Aruppukottai
104	High Rainfall Zone	-Kanyakumari/ Peechaparaii
105	High Altitude and Hilly Zone	-Thadiankudisal
	Uttaranchal	
106	Hill Zone	-Ranichauri
107	Bhabar and Tarai Zone	-Pantanagar
	Uttar Pradesh	
108	Western Plain Zone	-Daurala
109	Mid-Western Plain Zone	-Nagina/ Sahajahanpur
110	South Western Semi-Arid Zone	-Madhuri Khund
111	Central Plain Zone	-Kanpur
112	Bundelkhand Zone	-Bharari
113	North Eastern Plain Zone	-Sardarnagar
114	Eastern Plain Zone	-Kumarganj
115	Vidhyan Zone	-Mirzapur

	West Bengal	
116	Hilly Zone	-Pedong/ Kalimpong
117	Tarai Zone	-Pundibari
118	Old Alluvial Zone	-Ranudia – Majhian
119	New Alluvial Zone	-Mohanpur
120	Laterite and Red Soil Zone	-Jhargram
121	Coastal Saline Zone	-Mathurapur/ Kakdweep
	North East Hilly Region	
122	Alpine Zone	-Hill of Arunachal Pradesh
123	Temperate Sub Alpine Zone	- Shergaon - Sangti (Arunachal Pradesh)
124	Sub Tropical Hill Zone	-Barapani-Shillong (Meghalaya)
125	Sub-Tropical Plain Zone	-Sanghaipet-Imphal
126	Mild Tropical Hill Zone	-Medziphema (Nagaland)
127	Mild Tropical Plain Zone	-Lembucherra – Agartala (Tripura)

D) Agro-ecological Regions by the NBSS & LUP

Since all the above mentioned approaches use State as a unit for subdivision, many zones having similar agro-climatic characteristics but occurring in different States have been created. Moreover, adequate attention was not paid in these approaches to soils which is the country's most important agricultural resource. In order to overcome these lacunae, the National Bureau of Soil Survey & Land Use Planning (NBSS & LUP) has recently brought out a 21-zone agro-ecological regional map of the country, essentially based on physiography, soils, bio-climatic types, and growing period which influences the supply of water for plant growth. This map is essentially based on 50 years data of over 350 meteorological stations and up-to-date soils database available in the country. The agro-ecological regions identified are:

I. Arid Ecosystem:

1. *Western Himalayas, Cold Arid Eco-region with Shallow Skeletal Soils:* The region covers 4.7% of the land area mainly in the Districts of Ladakh and Gilgit. It has mild summers and severe winters, with mean annual temperature and rainfall of less than 80 C and 150 mm, respectively. The annual growing period is less than 90 days. While the Northern part is covered under permanent snow, the valley areas show skeletal and calcareous soils. It has great potential for growing dry fruits like apricot and flowers like roses in valleys.

2. *Western Plain, Hot Arid Eco-region with Desert and Saline Soils:* It covers 9% of the land area in the Western Rajasthan, South-western Haryana and Punjab, Kutch Peninsula and Northern Kathiawar Peninsula. It has hot summers and cool winters, with an annual rainfall of less than 300 mm and growing period of less than 90 days. The soils are sandy and saline. Rainfed agriculture is the traditional practice. Drought and salinity are the major constraints.

3. *Deccan Plateau, Hot Arid Eco-region with Mixed Red and Black Soils:* It includes the Districts of Raichur and Bellary of Karnataka, and Anantapur of Andhra Pradesh covering 1.4% of the land area. It is characterized by hot and dry summers and mild winters, with an annual rainfall ranging from 400 to 500 mm. The growing period is less than 90 days. The soils are shallow to medium red loamy and deep clayey black.

Rainfed farming is most common. Prolonged dry spells and soil erosion are the major problems.

II. Semi-arid Ecosystem:

4. *Northern Plain and Central Highlands, Hot Semi-arid Eco-region with Alluvium - derived Soils:* It occupies 10% of the land area covering part of northern plain, central highlands and Gujarat plain. It has hot and dry summers and cool winters, with rainfall varying between 400 and 800 mm. The growing period ranges from 90 to 150 days. Soils are loamy and the terrain is interspersed by sand dunes. Rainfed farming is common, with intensive cultivation in areas irrigated through tube wells. Imperfect drainage leading to salinity and lowering of ground water due to over-exploitation are the major constraints.

5. *Central (Malwa) Highlands and Kathiawar Peninsula, Hot Semi-arid Eco-region with Medium and Deep Black Soils:* It covers 5.6% of the land area in the Western Madhya Pradesh, Eastern Rajasthan and Gujarat States. It has hot and dry summers and mild winters, with rainfall ranging from 600 to 900 mm. The growing period ranges from 90 to 150 days. Soils are loamy to clayey deep black. Dry farming is the common practice. Frequent dry spells, imperfect drainage, salinity and alkalinity are the major constraints.

6. *Deccan Plateau, Hot Semi-arid Eco-region with Shallow and Medium (Inclusion of Deep) Black Soils:* It includes most of Maharashtra and Northern part of Karnataka and Andhra Pradesh covering 10% of the land area. It has hot summers and mild winters, with rainfall ranging from 600 to 1000 mm. The growing period ranges from 90 to 150 days. It is characterized by medium to deep black soils. Rainfed agriculture is the traditional practice and prolonged dry spells adversely affect crop growth. The area has high productivity potential under judicious irrigation with watershed-based management.

7. *Deccan Plateau and Eastern Ghats, Hot Semi-arid Ecoregion with Red and Black Soils:* It covers part of the Deccan Plateau and Eastern Ghats in the State of Andhra Pradesh accounting for 6.3% of the land area. It has hot summers and mild winters, with 600 to 1000 mm rainfall and 90 to 150 days growing period. It has medium to heavy red and loamy black cotton soils. Rainfed agriculture is common and rice is cultivated under irrigation. Imperfect drainage, salinity and erosion are the major problems.

8. *Eastern Ghats (TN Uplands) and Deccan Plateau, Hot Semi-arid Eco-region with Red Loamy Soils:* It includes Tamil Nadu uplands and Western Karnataka covering 6.9% of land area. It has hot and dry summers and mild winters, with a rainfall of 600 to 1000 mm. The growing period varies from 120 to 150 days. Rainfed agriculture is common and rice is grown under irrigation. Erosion and drought due to coarse soils are the major problems.

III. Sub-humid Ecosystem:

9. *Northern Plain, Hot Sub-humid Eco-region with Alluvium - derived Soils:* It covers part of Northern Indo-Gangetic plain occupying 3.7% of the land area. It is characterized by hot to warm summers and cool winters receiving 1000 to 1200 mm rainfall. The growing period ranges from 150 to 180 days. It has deep loamy alluvial soils. Both rainfed and irrigated agriculture are followed. Poor water management, water logging and salinity are the major problems.

10. *Central Highlands (Malwa & Bundelkhand), Hot Sub-humid Eco-region with Medium and Deep Black Soils:* It covers part of the central highlands mainly in the Districts of Arisen, Sager, Bhopal, Sehore, Shajapur and Hoshangabad in Madhya Pradesh. It occupies 2.5% of the land area. Hot summers and mild winters with 1000 to 1500 mm rainfall and 150 to 180 days growing period are the main features. It has moderately deep black soils. Rainfed and irrigated farming are practiced. Inundations along major streams and drought during Kharif season are the major problems.

11. *Deccan Plateau and Central Highlands (Bundelkhand), Hot Sub-humid Eco-region with Red and Black Soils:* It comprises the Bundelkhand part of Madhya Pradesh and North-eastern part of Vidarbha region covering 4.2% of the land area. It is characterized by hot summers and mild winters, with 1000 to 1500 mm rainfall. The growing period varies from 150 to 180 days. It has medium red and heavy black soils. Both rain fed and irrigated farming are practiced. Cracking clay soils and soil erosion are the major problems.

12. *Eastern Plateau (Chhattisgarh Region), Hot Sub-humid Eco-region with Red and Yellow Soils:* It constitutes Chhattisgarh region of Madhya Pradesh and South-west highlands of Bihar covering 4% of the land area. It is characterized by hot summers and cool winters, with 1200 to 1600 mm rainfall. The growing period ranges between 150 and 180 days. The soils are medium to heavy and non-calcareous. Rainfed farming is common and rice and wheat are grown under irrigation. Severe erosion, partial water logging and seasonal drought are the common problems.

13. *Eastern (Chhota Nagpur) Plateau and Eastern Ghats, Hot Sub-humid Eco-region with Red Loamy Soils:* It includes Chhota Nagpur Plateau of Bihar, Western part of West Bengal, Orissa, and Bastar region of Madhya Pradesh covering 8.5% of the land area. It has hot summers and cool winters, with a rainfall of 1000 to 1600 mm and 150 to 180 days growing period. The soils are red loamy and non-calcareous. Rainfed farming is more common, seasonal drought and severe soil erosion are the major problems.

14. *Eastern Plain, Hot Sub-humid with Alluvium - derived Soils:* It covers North-eastern Uttar Pradesh and Northern Bihar occupying 2.8% of the land area. It has hot summers and cool winters, with 1400 to 1600 mm rainfall. The growing period varies from 180 to 210 days. The soils are mainly alluvium. Rainfed and irrigated farming are practised. Flooding, imperfect drainage and salinity are the major constraints.

15. *Western Himalayas, Warm Sub-humid (Inclusion Humid) Eco-region with Brown Forest and Podzolic Soils:* It includes Jammu and Kashmir, Himachal Pradesh and North-western half of Uttar Pradesh covering 5.4% land area. It has warm sub-humid to cool humid climate, with mild summers and cold winters. The rainfall ranges from 1600 to 2200 mm and it has 150 to 210 days growing period. The soils are brown forest and podzolic. Agriculture is practised in valleys and terraces. Severe cold, deforestation, land slides, acidity, and imperfect drainage in valleys are the common problems.

IV. Humid-Per humid Ecosystem:

16. *Assam and Bengal Plains, Hot Humid (Inclusion Sub-humid) Eco-region with Alluvium - derived Soils:* It comprises the plains of the Brahmaputra

and the Ganga rivers, covering parts of Assam and West Bengal and representing 3.6% of the land area. It has hot summers and mild to moderately cool winters, with the rainfall ranging from 1400 to 2000 mm. The growing period is more than 270 days. The soils are slightly acidic. Flooding, waterlogging and acidity are the major problems.

17. *Eastern Himalayas, Warm Perhumid Eco-region with Brown Hill Soils:* It encompasses Northern Bengal and Assam, and most parts of Arunachal Pradesh and Sikkim covering 2.4% of the land area. It has mild summers and moderate to severe winters, with a rainfall exceeding 2000 mm. The growing period is more than 270 days. The soils are loamy brown forest with high organic matter. Shifting cultivation is the traditional farming system followed. It has evergreen forests and faces the problems of deforestation and soil erosion.

18. *North-eastern Hills (Purvachal) Warm Perhumid Eco-region with Red and Lateritic Soils:* It constitutes North-eastern hilly States of Nagaland, Meghalaya, Manipur, Mizoram, and South Tripura covering 3.3% of the land area. It has warm summers and cold winters, with the rainfall ranging from 1600 to 2600 mm. The growing period exceeds 270 days. The soils are loamy red, yellow, and lateritic with slight acidity. Shifting cultivation is common leading to deforestation and severe erosion. It has tropical moist deciduous forests.

V. Coastal Ecosystem:

19. *Eastern Coastal Plain, Hot Sub-humid Eco-region with Alluvium - derived Soils:* It covers the Eastern coastal plain extending from Cauvery Delta to Gangetic Delta and occupies 2.5% of the land area. It has hot summers and mild winters, with an annual rainfall of 1200 to 1600 mm. The growing period ranges from 150 to 210 days. The soils are mainly clayey with slight acidity. Rainfed and irrigated rice farming are practised. Imperfect drainage and salinity are the major constraints.

20. *Western Ghats and Coastal Plains, Hot Humid - Perhumid Eco-region with Red, Lateritic and Alluvium - derived Soils:* It constitutes Western coastal plains of Maharashtra, Karnataka, and Kerala States covering 3% of the land area. It has hot summers, with rainfall exceeding 2000 mm. The growing period is more than 270 days. It has red, lateritic and alluvial soils. Water logging and severe erosion are the major problems. It has high potential for export-oriented plantation crops.

VI. Islands Ecosystem:

21. *Islands of Andaman-Nicobar and Lakshadweep, Hot Perhumid Eco-region with Red Loamy and Sandy Soils:* It comprises the Andaman and Nicobar Islands in the East and Lakshadweep in the West covering a meager 0.3% of the land area. The climate is typified by tropical conditions and the rainfall ranges from 1600 to 3000 mm. The growing period exceeds 270 days. The soils of the Andaman and Nicobar Islands are medium to very deep, red loamy and acidic, and that of the Lakshadweep Islands are highly calcareous and sandy. Most of the area is under forest and the land use is dominated by plantation crops. Forest degradation leading to severe erosion and inundation of coastal areas leading to saline marshes are the major constraints. It has greater potential for growing sustainable oil palm plantations.

2.5 SUMMARY

- **Agro-ecosystems** are those ecosystems that are modified for the purpose of agricultural production. They are found all over the world from wetland to lowlands, mountains and dry lands and comprise monocultures, polycultures, mixed systems, including crop-livestock, agro-forestry as well as aquaculture.
- An agro-ecosystem consists of both **biotic** (crops, trees, forage livestock, wildlife, insects, soil bacteria, non-crop vegetation) and **abiotic** components (air, climate, soil).
- Agro-ecosystems differ from natural ecosystems in a number of ways. Natural ecosystems have a continuous reinvestment of nutrients and energy; they are self-regulating while **agro-ecosystems don't have the capacity for self-regulation** (mediating nutrient cycling, mediating control of organisms).
- The **key processes** in an agro-ecosystem are **water balance, energy flow and nutrient cycling.**
- The factors affecting the **structure and function** of agro-ecosystem such as climate, competition between species of crops and weeds and agricultural practices such as ploughing, crop rotation, irrigation, pest and weed control, introduction of fertilizers and high yielding varieties have been discussed.
- The various agro-ecological and agro-climatic zones of the Indian subcontinent have been discussed.

2.6 TERMINAL QUESTIONS

1. How are agro-ecosystems similar to natural ecosystems? How are they different? Describe the differences that result from human management of agro-ecosystems for agricultural production.

2. a) What do the terms open and closed mean in relationship to nutrient cycles?
   b) Why are agro-ecosystems relatively open with respect to nutrient cycles?
   c) Describe the processes that lead to agro-ecosystems having open nutrient cycles.

3. Enlist the major ecological regions of India identified by National Bureau of Soil Survey and Land Use Planning.

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