

Block

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AGROFORESTRY SYSTEMS

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PROGRAMME DESIGN COMMITTEE

Prof. Punjab Singh, Former Vice Chancellor
Banaras Hindu University, Varanasi (UP)

Dr. V.N. Sharda, Director
CSWCR&TI, Dehradun (Uttarakhand)

Dr. H. P. Singh, Ex-Director, CRIDA
Santoshnagar, Hyderabad (AP)

Dr. M.A. Khan, Director
ICAR Research Complex for Eastern Region
ICAR Parisar, Patna (Bihar)

Er. K.P. Tripathi, Principal Scientist
CSWCR&TI, Dehradun (Uttarakhand)

Dr. R.K. Sharma, Professor
Water Technology Centre, IARI, New Delhi

Dr. A.K. Tiwari, Head
CSWCR & TI, Research Centre, Chandigarh

Prof. O.N. Srivastava, Ex-Head, NIRD
Hyderabad (AP)

Dr. R.N. Prasad, Ex-ADG (Soils)
ICAR, New Delhi

Shri Nivas Sharma
Principal Scientist (Rtd.)
CRIDA, Hyderabad (AP)

Dr. L.S. Bhushan
CSWCR & TI Research Centre, Agra (UP)

Dr. A.K. Singh, DDG (NRM)
ICAR, New Delhi

Dr. M.A. Shankar, In-charge, CRIDA
UAS, Bangalore (Karnataka)

Dr. Arun Verma, Ex-ADG (Animal
Husbandry) ICAR, New Delhi

Prof. N.P. Singh, Joint Director
ICAR Research Complex for NEH Region
Tripura Centre, Lembucherra (Tripura)

Dr. M.C. Nair, Director, CEE, IGNOU

Dr. Indrani Lahiri, ARD, RSD, IGNOU

Prof. Madhulika Kaushik, SOMS, IGNOU

Prof. Vijayshri, SOS, IGNOU

Faculty Members (SOA, IGNOU)

Dr. M.K. Salooja, Director

Prof. B. S. Hansra, Professor

Dr. S.K. Yadav, Associate Professor

Sh. Mukesh Kumar, Assistant Professor

Dr. Praveen Kumar Jain,

Assistant Professor

Dr. P. Vijayakumar, Assistant Professor

Dr. Mita Sinhamahapatra,

Assistant Professor

Sh. N.S. Dhama, Sr. Consultant

Sh. Kumar Bhatia, Sr. Consultant

Sh. Jaya Raj, Sr. Consultant

Dr. D. S. Khurdiya, Sr. Consultant

Dr. J.S. Sindhu, Sr. Consultant

Prof. Ranvir Kumar, Sr. Consultant

Programme Coordinators : Prof. B.S. Hansra and Sh. Mukesh Kumar

Course Coordinators : Sh. Mukesh Kumar and Prof. Ranvir Kumar

BLOCK PREPARATION TEAM

Unit Writers

Dr. J.C. Tiwari (Unit 1 and 3)
Sr. Scientist, Division-2
CAZRI; Jodhpur-342003 (Rajasthan)

Dr. J.N. Daniel (Unit 2)
Director, Baif Development
Research Foundation, Wajre
Pune-411058 (Maharashtra)

Editors

Prof. Ranvir Kumar
Sr. Consultant, SoA, IGNOU, New Delhi

Sh. Mukesh Kumar
Assistant Professor, SoA, IGNOU
New Delhi

MATERIAL PRODUCTION

Ms. Pushpa Gupta
Dy. Registrar (Publications)
SoA, IGNOU, New Delhi

Ms. Rajshree Saini
(Proof Reader)
SoA, IGNOU, New Delhi

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BNRI-106 HORTICULTURE AND AGROFORESTRY SYSTEMS

Agroforestry is an ancient traditional practice of the integration of farming with forestry practices on the farm to the benefit of farmers. Agroforestry is a combined productive-protective land use system which in addition to providing food, wood, fodder and many other tree based products, also conserves land resources. Planning of agroforestry is essential to manage compatible species for maximizing their positive interactions and minimizing the negative interactions. It is of paramount importance to document existing traditional agroforestry practices/systems based on existing tools and methodologies.

Establishment of an orchard requires high level of expertise and planning to realize the benefits of a considerable investment. Nursery plays an important role in growing quality plants and seedlings of fruits, vegetables and forestry plants under controlled and optimum conditions. A number of environment, handling and management parameters influence the production of quality plants and seedlings.

Vegetables and fruits are essential for providing balanced diet for good human health. In order to meet the growing demand and supplement the income, the area under fruits and vegetables is increasing. Adoption of organic practices and the value addition by post harvest processing and preservation will go a long way in boosting income and providing reliable products as and when required. Latest technologies/ practices and high yielding varieties of fruits and vegetables need to be adopted to realize their full potential.

Cost-effective and environmentally safe strategies are absolutely essential for the use of pesticides/insecticides for effective control and management of insects/pests and diseases.

Transportation, grading, refrigeration, packaging, labeling and other marketing techniques are of crucial importance to producers, marketers and consumers of fresh produce. Marketing of fresh produce plays an important role in growth of this industry and agricultural sustainability. In the changed scenario, medicinal and aromatic plants have an important role to play to prevent/cure disease and maintain health whereas aromatic plants are used for aroma and flavour. Plants and plant based products have been used traditionally in India from the time immemorial.

BLOCK 1 AGROFORESTRY SYSTEMS

Agroforestry is an ancient traditional practice which refers to the integration of farming with forestry practices on the farm to the benefit of farmers. Agri-silvicultural plantation is a major agroforestry system which has potential of making significant contribution to agricultural development and land management. Agroforestry is now used as a multiple production agricultural system instead of being merely the subsidiary of forestry. Agroforestry is thus a combined productive-protective land use system which provides food, wood, fodder and many other tree based products and at the same time conserves land resources.

Planning of agroforestry is of crucial importance in order to bring compatible species together and manage them for maximizing their positive interactions and minimizing the negative interactions. Fertility of land and moisture status for crop growth also need to be considered in planning an agroforestry system. Agroforestry has two main objectives: productivity involving large number of outputs and sustainability (which implies conservation, or even improvement, of the environmental aspects of the system).

Most of the agroforestry systems deal with only a few agroforestry practices. It is absolutely necessary to be familiar with the agroforestry approaches related to practical aspects. Existing or traditional agroforestry practices/systems evolved under site specific conditions need to be documented based on existing tools and methodologies.

Unit 1 deals with objectives, importance, concepts, and potentials of agroforestry and distinction between term agroforestry “system” and “practice”. Various agroforestry systems and practices and benefits of agroforestry as a land management unit are also dealt with.

Unit 2 covers management aspects of agroforestry in relation to tree, intercrop and livestock management. Environmental and economic benefits emanating from agroforestry and extension aspects of agroforestry are also discussed in the unit.

Unit 3 deals with diagnosis and design (D & D) exercise and PRA methods for choice of species and needs and conduct field exercise. Survey of multipurpose tree species, indigenous traditional knowledge of agroforestry systems, shelterbelts and aqua forestry and concepts of natural resource survey and economic consideration are also covered in the unit.

UNIT 1 AGROFORESTRY SYSTEMS

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1.0 OBJECTIVES

After studying this unit, you should be able to:

- define agroforestry and its objectives;
- explain importance, concepts and potentials of agroforestry;
- distinguish between term agroforestry “system” and “practice”;
- describe various agroforestry systems and practices; and
- outline benefits of agroforestry as a land management unit.

1.1 INTRODUCTION

The term “agroforestry” refers to the integration of farming with forestry practices on the farm for the benefit of farmers. In fact, cultivating trees in association with agriculture crops is an ancient practice that farmers have used throughout the world. There are numerous examples of traditional land use practices involving combined production of trees and arable crops on the same piece of land in many parts of the world, what is now known as ‘agroforestry’ in general. Establishing agri-silvicultural plantations has now become an important objective of forestry

plantation, which is now considered a major agroforestry system. The history of agri-silvicultural plantation dates back to 1806 when plantation of teak (*Tectona grandis*) was established in Myanmar (Burma) using a method called 'taungya'. Taungya system was intended to establish forest plantations using landless labourers and in return for performing forestry tasks, the labourers were to be allowed to cultivate land between rows of tree seedlings to grow agricultural produce for a few years. The practice became increasingly widespread. It was introduced in South Africa as early as 1887 and taken to Chittagong and Bengal areas in colonial India in 1890. The foresters working on such a system never imagined the system as being capable of making significant contribution to agricultural development, or its potential as a land management system.

Deteriorating food situation in many areas of developing world, the energy crisis of 1970s and consequent shortage of fertilizers, the re-assessment of developing policies by World Bank and a reawakening of scientific interest in both intercropping and farming systems contributed to the general acceptance of agroforestry as a system of land management applicable to both the farm and the forest. Realizing the potential benefits of agroforestry in enhancing agricultural production and tree produce, International Council for Research in Agroforestry (ICRAF) was established at Nairobi, Kenya in 1977 renamed in 1991 as the International Centre for Research in Agroforestry. It is now known as World Agroforestry Centre with basic mandate to support, plan and co-ordinate research and developmental activities combining the land management system of agriculture and forestry, on a world wide basis.

Today, agroforestry is being used as a multiple production agricultural system instead of being merely the subsidiary of forestry. Moreover, the potential of agroforestry for soil improvement and conservation is now well accepted. Agroforestry is thus a combined productive-protective land use system, which is capable of yielding food, wood, fodder and many other tree based products and at the same time conserves land resources.

In the next unit, management aspects of agroforestry in relation to tree, intercrop and livestock management, environmental and economic benefits emanating from agroforestry and extension aspects of agroforestry will be covered.

1.2 WHAT IS AGROFORESTRY?

In a very simple term, agroforestry is an art and science of growing woody and non-woody plants together on the same unit of land for a range of benefits. However, many definitions of agroforestry were proposed at different times.

1.2.1 Some Important Definitions of Agroforestry

- a) Agroforestry refers to those land use practices in which woody perennial (trees, shrubs, vines, bamboos, palms, etc.) are grown in combination with agricultural crops or pastures, sometime with livestock and other animals (e.g., insects such as bees, fish) and in which there are both ecological and economic interactions between woody plants and other components.
- b) Agroforestry land use is the deliberate interaction of woody and non-woody plant components (sometimes with animals) in order to generate multiple products and services.

- c) Agroforestry may be defined as an efficient and integrated land use management system by raising certain agricultural crops, forest tree species and/or animals simultaneously and sequentially on the same unit of land to increase overall production under a particular set of climatic and edaphic conditions and socio-economic status of local people.

Above definitions were later refined through “in-house” discussion at World Agroforestry Centre and following definition of agroforestry was suggested:

- d) Agroforestry is collective name for land use systems and technologies where woody perennials are deliberately used on same land-management units as agricultural crops and/or animals in same form of spatial arrangement or temporal sequence.

As now you are familiar with the term agroforestry and its definition, we will now discuss in brief the aims of agroforestry.

1.2.2 Aims of Agroforestry

Agroforestry aims at achieving the following:

- manage land efficiently so that its productivity is increased and restored;
- use available resources efficiently and economically;
- generate employment opportunities for rural poor;
- provide raw material for developing cottage industries in rural areas (raw material namely, wood, pulp, fiber, medicinal herbs, gum, wax, resins, lac, tannins, dye, oil and oil cakes, etc.); and
- provide basic needs of small and marginal farmers for food, feed, fodder, fruits, fire wood, small timber, etc.

Besides the above, agroforestry practices have immense potential for soil improvement and conservation. Agroforestry is truly a sustainable land use system, as $\text{Production} + \text{Resource Conservation} = \text{Sustainability}$. Agroforestry not only enhances overall productivity of land but conserves and improves soil resource, the most important natural resource as well.

1.3 BASIC CONCEPTS OF AGROFORESTRY

Agroforestry systems represent an interface between agriculture and forestry and encompass mixed land use practices. These practices have been developed primarily in response to special needs and conditions, especially of tropical developing countries that have not been satisfactorily addressed by advances in conventional agriculture and forestry. The most common concept of various agroforestry systems deals with “the purposeful growing or deliberate retention of trees with crops and/or animals in interacting combinations for multiple products or benefits from same land management unit”. This is the essence of agroforestry. Conceptually, following three attributes are normally possessed by all agroforestry land use systems (Nair, 1993):

- **Productivity:** Agroforestry aims at maintaining or increasing production as well as productivity of land which can be improved by increased output of tree products; improved yield of companion arable crops and/or grasses; reduction in inputs like fertilizers, pesticides, etc. and increased labour efficiency.

- **Sustainability:** By conserving production potential of resource base, mainly through beneficial effects of woody perennials on soils, agroforestry can achieve and maintain conservation and fertility goals.
- **Acceptability:** The fact that agroforestry is a relatively new word for some old set of practices means that, in some cases, agroforestry has already been accepted by farming community. However, the word “acceptability” means that improved or new agroforestry technologies introduced to new areas should also conform to local farming practices.

Above attributes are characteristics of all kinds of agroforestry which form the basis of evaluation of various agroforestry systems.

Check Your Progress 1

- Note:** a) Use the space below for your answers.
 b) Compare your answers with those given at the end of unit.

1) Indicate if the following statements are true or false by putting a tick marks (✓) in relevant box.

	True	False
(a) Cultivation of trees in association with agricultural crops is a very recent process.	<input type="checkbox"/>	<input type="checkbox"/>
(b) ‘Taungya’ system of agri-silviculture first started in Myanmar (Burma).	<input type="checkbox"/>	<input type="checkbox"/>
(c) ICRAF is now named as World Agroforestry Centre.	<input type="checkbox"/>	<input type="checkbox"/>
(d) Agroforestry is multiple production forestry.	<input type="checkbox"/>	<input type="checkbox"/>
(e) Agroforestry land use is the deliberate interaction of woody and non-woody plant components.	<input type="checkbox"/>	<input type="checkbox"/>
(f) Sustainability = Resource depletion + Production.	<input type="checkbox"/>	<input type="checkbox"/>
(g) Productivity, sustainability and acceptability are conceptual attributes of agroforestry.	<input type="checkbox"/>	<input type="checkbox"/>

2) Fill in the blanks with appropriate word (s).

- (a) Agroforestry is a land management system that is applicable to both farm and
- (b) Agroforestry is art andof growing woody andplants together in same unit of land.
- (c) Agroforestry has immense potential for soil and conservation.
- (d) Conceptually, agroforestry is an combination of trees with crops and/or animals for multiple products or benefits from same land management unit.

1.4 IMPORTANCE AND SCOPE OF AGROFORESTRY

The practice of agroforestry is of immense importance in India in order to increase food production to meet the needs of our growing population, conserve natural resources such as soil and water and sustain rainfed agriculture. Nearly two-third geographical area of the country comprises of arid, semi-arid and dry sub-humid regions depending on rains. Properly distributed trees promote agricultural activities particularly in these areas. Tree growth in such cases conserves soil moisture, increases soil fertility, protects field crops against effects of winds and improves micro-climate conducive for plant growth leading to enhanced crop productivity and higher returns. Major components of Agroforestry System are shown in Fig.1.1.

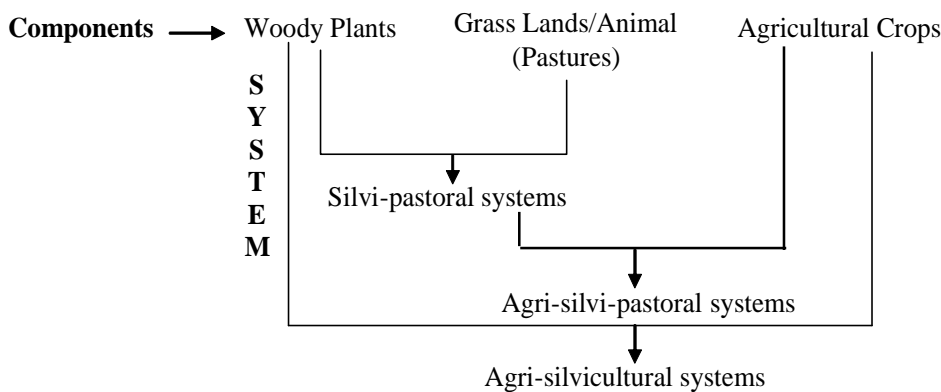


Fig.1.1: Major Agroforestry Systems

In addition to ameliorating adverse climatic conditions, tree culture ensures readily available and adequate supply of cheap fuel/fire wood in villages. It enables cow dung which is still burnt on large scale (about 60 per cent) to be diverted for its use as farmyard manure, a rich organic source of essential elements. Besides, fuel wood trees, fruits and/or timber yielding trees not only enrich the diet of rural population but also meet demand of farmers and small scale industries for timber.

The integration of fodder trees in agroforestry also provides much needed top feed (tree leaf fodder) for sustenance of livestock during lean periods. Agroforestry is thus a versatile multiple cropping system providing a large number of products from the same land management unit and also conserving soil from erosion and restoring its fertility.

By now you may be aware of the importance of agroforestry. In the ensuing discussion, we will elaborate the potential and scope of agroforestry.

1.4.1 Agroforestry Maximizes Production

Agroforestry practices have led to 20 per cent increase in the production as compared to only agricultural cropping in Punjab, Haryana and Western Uttar Pradesh. Growing Eucalyptus and Poplar trees on farm bunds in these regions, total production (wood + food grain) has increased considerably giving more returns to farmers.

In India 160 million hectare land is characterized as wastelands and wherever possible, only dry land agriculture is practiced. In such an agricultural scenario, incorporation of multipurpose trees in crop fields can produce 4.5 tonnes nutritious

leaf fodder per hectare per year and 6-8 tonnes per hectare fire wood during every four years period in addition to food grains.

1.4.2 Agroforestry for Timber Production

Agroforestry practices in irrigated areas in Punjab, Haryana, Uttar Pradesh, Gujarat and few south Indian states have yielded about 2.5 cubic meter timber per hectare in addition to food grain production. In rainfed areas, however, plantation of timber on farm bunds yields just half of this amount of timber (≈ 1.25 cubic meter) as compared to irrigated areas.

1.4.3 Agroforestry for Increasing Income

Agroforestry provides several options to the farmers. As per their needs, farmers can select fuel or fodder or fruit trees and as well as grass species for forage. To work out the potential of agroforestry in rainfed situation, Aga Khan Foundation conducted a study in Matsan village of Gujarat considering factors such as fulfillment of basic needs, per capita income and ratio between income and expenditure revealed that a farmer with land holding of 2 hectare could fulfill his/her 79 per cent requirement through sole agriculture in normal climatic conditions. However, in case of partial drought situation, only 40 per cent requirement can be met as besides food grain and fodder scarcity, several other household requirements are also affected. The adoption of agroforestry by the same farmer, 18 per cent return on the expenditure for procuring farm inputs, even under partial drought or low rainfall conditions could be expected. Agroforestry is thus more remunerative than the sole agriculture.

1.4.4 Agroforestry and Industry

There are 1600 woody species in our country, of which 200 are of industrial importance. Teak (*Tectoma grandis*), Shisam (*Dalbergia sisso*), Sal (*Shorea rolzusta*), Dhawda (*Anagbisus latifolia*), Sandal (*Santarum album*), Kher (*Acacia catechu*), Semal (*Salmelia malabarica*), Neem (*Azadirachta indica*), Babool (*Acacia species*), Tun (*Ceelrala toona*), Anjan (*Hardwicria binata*), various species of Eucalyptus and Acacia, etc. are few important species from industrial point of view. Following industries utilize agroforestry trees and their produce:

- Woody industry: Wood as furniture, construction material, handicraft, etc.;
- Paper industry: Wood pulp (Eucalyptus, Poplar, etc.);
- Match industry: Soft wood for match sticks (Semal, etc.);
- Herbal medicine industry: A range of herbal products;
- Pattal industry: Bio-degradable, use and throw plates;
- Lather industry: For colouring leather (tannery);
- Silk industry: For housing and feeding silkworm (Oak, mulberry);
- Lac industry: For housing and feeding lac insect (Oak); and
- Katha (*Catechu*) industry: Katha from *Acacia catechu* wood.

1.4.5 Environmental Benefits

Agroforestry can achieve the following with regard to environment.

Through Soil Process

- Control soil erosion;
- Maintain soil organic matter and hence soil fertility;
- Add substantial amount of nitrogen through nitrogen fixing trees;
- Capture mineral nutrients from deeper soil layer and recycle to top soil;
- Reduce soil acidity (through leaf litter);
- Reclaim degraded soil;
- Improve soil biological activity and nitrogen mineralization through shade; and
- Enhance mycorrhizal association through tree-crop mixtures.

Through Bio-physical Interactions

- Improve the capture of rainfall and mineral nutrients; and
- Improve the light, water and nutrient use efficiency of plants.

Other Environmental Benefits

- Nitrogen fixing trees have more nodules when in close contact with non-nitrogen fixers (like crops, grasses, etc.); and
- Trees provide beneficial shelter to associated crops.

Thus, agroforestry aims at introducing woody plants to farmers' land in order to increase its overall production and improve processes such as nutrient retention and recycling within the system, build up soil fertility over time to help prevent soil loss leading to crop yield decline and so on. More over, trees in crop lands also lead to better utilization of most important environmental resources i.e., light and water. Agroforestry has immense potential for production of multitudes of commodities, which in turn have direct positive impact on farmers' income, and consequent economic and livelihood security.

Check Your Progress 2

Note: a) Use the space below for your answers.

b) Compare your answers with those given at the end of unit.

1) Fill in the blanks with appropriate word (s)

- a) Nearly two-third geographical area of India is.....,and
- b) In Punjab, Haryana and Western Uttar Pradesh, agroforestry increased overall farm production to the tune of per cent over sole agriculture.
- c) Eucalyptus and Poplaris used for making in paper industry.

- d)wood is used for making *Kattha*.
 - e) In India million hectare land is characterized as wasteland.
- 2) Indicate if the following statements are true or false by putting a tick marks (✓) in relevant box.

	True	False
a) In agroforestry practices, trees on farm lands decrease soil fertility.	<input type="checkbox"/>	<input type="checkbox"/>
b) Agroforestry practices can minimize the use of cow dung as cooking and heating fuel.	<input type="checkbox"/>	<input type="checkbox"/>
c) Agroforestry is capable of maximizing farm production.	<input type="checkbox"/>	<input type="checkbox"/>
d) Agroforestry has only production value.	<input type="checkbox"/>	<input type="checkbox"/>
e) Soft wood of Semal (<i>Salmelia malabarica</i>) is used to produce match sticks.	<input type="checkbox"/>	<input type="checkbox"/>
f) Agroforestry increases soil acidity through incorporation of leaf litter on the crop fields.	<input type="checkbox"/>	<input type="checkbox"/>
g) Trees provide beneficial shelter to associated crops.	<input type="checkbox"/>	<input type="checkbox"/>

3) List two benefits of agroforestry due to occurrence of bio-physical interactions in agroforestry practices.

- a)
-
- b)
-

1.5 AGROFORESTRY SYSTEMS AND PRACTICES

The word “agroforestry systems” and “practices” are often used synonymously in agroforestry literature. Though it is true to some extent, however, some distinction can always be made between words “system” and “practices”. *An agroforestry system is a specific local practice of agroforestry, which is generally wide spread and characterized by environment, plant species and their arrangement, management and socio-economic functioning.* For example, *Prosopis cineraria* (locally known as ‘*khejari*’) based agroforestry system of western part of Rajasthan is spread in 60per cent of the total area (19.6 million hectare) of western Rajasthan.

An “agroforestry practice” is a *distinctive arrangement of components in time and space.* Although hundreds of agroforestry systems have been recorded, they all consist of a few agroforestry practices. In other words, similar practices are found in various agroforestry systems in different situation.

1.5.1 Classification of Agroforestry Systems

There is no universally accepted approach for classifying agroforestry systems. Generally, four criteria are used for classification of agroforestry systems.

- Structure of the system (nature and arrangement of components).
- Function of the system (role and output of components).
- Agro-ecological zone based classification (the area where system exists or is adoptable).
- Socio-economic criteria (socio-economic scales and management levels of the system).

Each of these criteria has merits and applicability as well as limitations in a specific situation. Since there are only three basic sets components (woody perennials, herbaceous plants and animals) that are managed by farmers in all agroforestry system, it would be logical to classify agroforestry systems on the basis of nature of components. In general, agri-silvicultural system, silvi-pastoral system and agri-silvi-pastoral system are three major forms of agroforestry systems. Under these systems, various forms of agroforestry practices are categorized.

1.5.2 Agroforestry Practices

Agricultural crops and trees are the components of agri-silvicultural systems. Here agricultural crops refer not only to arable crops but they also include shrubs, vines, fruit trees, etc. The major practices under the system are as under:

Multipurpose Tree Species (MPTs) on Croplands: Generally, trees are scattered irregularly on the crop lands, however, they are also found distributed according to some systematic pattern on field bunds, terraces and on field boundaries. Scattered trees of *Prosopis cineraria* (*khejri*) on agricultural fields in Western Rajasthan, *Acacia nilotica* in Bundelkand region of Uttar Pradesh and northern part of Madhya Pradesh, and various fruit trees on terrace boundaries in Uttarakhand and Himachal Pradesh are some typical examples of this practice commonly known as agri-silviculture practice. However, when agricultural crops are grown with fruit trees, the practice is generally referred to as agri-horticultural practice.

Improved Fallows: The fields where agricultural crops are grown are sometimes left fallow for a few years. During the fallow phase, woody species are planted and allowed to grow. This type of practice, pre-dominant in north-eastern states is commonly found in shifting cultivation areas. Shifting cultivation is a form of land use practice wherein forests are cleared and the land is used to grow agricultural crops. After a few years of cropping, the land is left fallow where trees are planted and allowed to grow. The farmers move from this area to a new area for repeating the process. The shifting cultivation in north-eastern region of India is also known as “Jhum cultivation”.

Taungiya: It is a combined stand of woody and agricultural crops, during early stage of tree plantation establishment.

Farm Boundary Plantations: In majority of agricultural landscapes in the country, farmers plant and maintain some MPTs on the boundaries of their crop fields. Such a type of tree plantation is categorized under agri-silvicultural system which

generally does not have any systematic pattern and farmers primarily maintain trees for protection of their crop land. However, in *Tarai* belt of Uttarakhand and Uttar Pradesh, Western Uttar Pradesh, Punjab and Haryana, farmers intensively grow Poplars and Eucalyptus on farm boundaries in systematic pattern for commercial purpose.

Home Gardens: Home gardens are also categorized under agri-silvicultural system and are very common in countries of south-east Asia and Kerala state in India. Their evolution lies in multistory stand structure of *Tropical Rain Forests* and therefore, they are found in the areas where *Tropical Rain Forests* are distributed. Tropical rain forests are very dense and highly diverse vegetation formation with multistrata tree canopies. Home gardens or home steads constitute intimate combination of various fruit trees, woody and non-woody vines, agricultural crops, etc. In Kerala state, home gardens, generally consist of coconut trees, cashew trees, black piper vines, other economically important woody species and agricultural crops, especially rice in same unit of land around residential units of one-fourth or even less than an acre area.

Shelterbelts and Wind Breaks: Shelterbelts are rows of trees around farm boundaries, which are primarily meant for protection of crops from high speed winds. Shelterbelts generally consist of three to five rows of trees. In both the cases, central rows consist of fast growing trees and side rows of small trees. On maturity, shelterbelts become pyramidal in shape, and are very effective in minimizing wind erosion particularly in arid and semi-arid areas. Wind breaks are also meant for the same purpose but they do not have any systematic plantation like shelterbelt. Only one row of trees around farms can be considered as wind break.

Above mentioned practices are important practices under agri-silvicultural system. In ensuing discussion, we will learn about following three important practices under silvi-pastoral systems.

Trees on Grasslands or Pastures: The practice is generally referred to as silvi-pastoral practice. In this practice, trees especially those yielding leaf fodder are generally scattered on grass land (range lands) or pastures. Village Gauchars are typical silvi-pastures, which are found in one form or other in entire rural areas of our country. They are common property resource (CPR) of villagers. In arid Western Rajasthan, they are abundantly distributed. Animals are important components of silvi-pastoral practice, as it is meant for their grazing and/or browsing. In systematic silvi-pastoral practices, grasses are grown between rows of MPTs, sometimes between rows of fruit trees also (when grasses are grown in association with fruit trees, the practice is also referred to as **horti-pastoral practice**, but essentially it is a part of silvi-pastoral system). For example, grasses between mango rows of trees in Uttar Pradesh, grasses in association with scattered trees of *Ber* (*Ziziphus* sp.) in Rajasthan.

Protein Banks: Production of protein-rich tree fodder on farm/grass lands (range lands) for cut- and- carry purpose.

Plantation Crops with Pastures and Animals: When livestock is reared under plantation crops (e.g., coconut, cashew, oil palm, etc.) and grasses, the practice is also referred to as silvi-pastoral, For example, cattle under coconut in South-East Asia and Sri Lanka. In such plantations, some grasses are also grown in their association.

The third main system is **agri-silvi-pastoral** system which includes agricultural crops, MPTs, grasses and/or animals as its components. Following major practices are covered under this system.

Home Gardens Involving Animals: When animals are reared in home gardens, the practice is considered under agri-silvi-pastoral system. This practice is common in Kerala, Andaman and Nicobar islands and in some/parts of costal Andhra Pradesh and Tamil Nadu.

Agricultural Lands with Fuel and Fodder Trees: When, fuel and fodder trees are grown on crop lands, it constitutes an agri-silvi-pastoral practice. Animals are involved at some point in the practice. This, practice though not very intensive is prevalent throughout the country in one form or the other.

Aqua-forestry: When trees are grown around fish ponds and tree leaves used as 'forage' for fishes, the practice is considered as a part of agri-silvi-pastoral system, as fish are ultimately used for human consumption. Thus, fish is considered a food commodity, tree leaves as a fodder, and small branches and twigs of trees forms fuel for cooking. These practices though not very common are sometimes found in low lands.

Apiculture with Trees: When trees are used for honey production, the practice is also grouped under agri-silvi-pastoral system. Besides, other components may be present in the practice, for example, crop lands or fruit orchards with other MPTs and honeybees (considered here as animal for producing food commodity 'honey' like cattle for 'milk').

Check Your Progress 3

Note: a) Use the space below for your answers.

b) Compare your answers with those given at the end of unit.

1) List three major systems of agroforestry.

a)

b)

c)

2) Fill in the gaps with appropriate word (s):

a) An Agroforestry system is a specific agroforestry practice characterized by....., and their arrangement, management and socio-economic functioning.

b) It is most logical to discuss agroforestry practices on the basis of nature of

c) 'Taungiya' is an agroforestry practice categorized under system.

d) 'Gauchars' are the example of typical system.

e) Aqua-forestry practice is categorized under system.

f) Farm boundary plantations are categorized under system.

3) Indicate if the following statements are true or false by putting a tick marks (✓) in relevant box.

	True	False
a) <i>Prosopis cineraria</i> (khejri) based agroforestry systems are found in western Rajasthan.	<input type="checkbox"/>	<input type="checkbox"/>
b) Multipurpose trees on croplands are example of silvi-pastoral practice.	<input type="checkbox"/>	<input type="checkbox"/>
c) 'Home gardens' is a agri-silvicultural practice.	<input type="checkbox"/>	<input type="checkbox"/>
d) Fruit trees + agricultural crops in same unit of land are referred to as agri-horticultural practice.	<input type="checkbox"/>	<input type="checkbox"/>
e) Aqua-forestry means irrigating agricultural crops with local water resources like ponds, wells, etc.	<input type="checkbox"/>	<input type="checkbox"/>
f) Trees on grasslands or pasture are generally referred to as silvi-pastoral system/practice.	<input type="checkbox"/>	<input type="checkbox"/>
g) The practice of growing agricultural species with grass species is known as agri-silvi-pastoral practice.	<input type="checkbox"/>	<input type="checkbox"/>
h) One of the major objectives of agroforestry is optimizing production from same unit of land.	<input type="checkbox"/>	<input type="checkbox"/>

1.6 LET US SUM UP

- Agricultural practices combining agricultural crops, trees, animals, etc. in same land management unit strive to upgrade environmental hospitability for plants and animals in order to enhance production and conserve land resources. Agroforestry covers those land use practices in which woody perennial (trees, shrubs, vines, bamboos, palms, etc.) are grown in combination with agricultural crops or pastures, sometime with livestock and other animals (e.g., insects such as bees, fish) and in which there are both ecological and economic interactions between woody plants and other components.
- Agroforestry is a sustainable land use system which aims at managing land efficiently for enhancing and restoration of productivity to meet the needs of our growing population and conserving natural resources particularly in rainfed regions.
- Enhancing productivity, sustainability of conservation and land fertility and acceptability by the farming community are three main attributes of agroforestry. Agroforestry is a versatile multiple cropping system providing a large number of products such as cheap fuel/fire wood, fruits and timber, fodder etc. from the same land management unit and also conserving soil from erosion and restoring its fertility.
- Agricultural crops which include arable crops, shrubs, vines, fruit trees, etc. and trees are the components of agri-silvicultural systems. The major practices under the system include multipurpose tree species (MPTs) on croplands, improved fallows, Taungiya, farm boundary plantations, home gardens,

shelterbelts and wind breaks. Trees in grasslands or pastures, protein banks and plantation crops with pastures and animals are the main practices under silvi-pastoral system.

- Home Gardens involving animals, agricultural lands with fuel and fodder trees, aqua-forestry and apiculture with trees are the important activities of agri-silvi-pastoral system whose components include agricultural crops, MPTs, grasses and/or animals.

1.7 KEYWORDS

Agricultural Crops	:	Common food grain crops, like wheat, rice, maize, pulses, oil seeds (soya bean, mustard, sunflower, etc.), vegetables, etc.
Agri-silvicultural System	:	A kind of agroforestry system, in which primarily woody component (MPTs) are grown in association with agricultural crops.
Agri-silvi-pastoral System	:	This is most diverse kind of agroforestry system, which has agricultural crops, MPTs, grasses, and/or animals as its component.
Agroforestry	:	In very simple term agroforestry is an art and science of growing woody and non-woody plants together on the same land unit for a range of benefits.
Agroforestry Practices	:	Agroforestry practice can be defined as distractive arrangements of various components (like, trees, agricultural crops, grasses animals, etc.) in time and space.
Agroforestry System	:	It can be defined a specific local practice of agroforestry, which is generally wide spread and characterized by environment, plant species and their arrangement, management and socio-economic functioning.
Crop Lands	:	Agricultural fields in which food grain, vegetable, oil seed, etc. are grown.
Edaphic	:	Soil related: describes the effect of soil characteristics, especially chemical or physical properties, on plants and animals.
Landuse	:	The term simply denotes the purpose for which land as being utilized. For example, land under forest cover is forest landuse, land under food grain crops in agricultural landuse, land which is used for residential purpose, roads, etc. will come under that particular landuse, etc.
MPTs	:	Multipurpose Tree Species.

- Mycorrhizal Association** : The fungus colonizes the host plants roots either intracellularly or extracellularly.
- Silvi-pastoral System** : A kind of agroforestry system, which has grass lands or pastures, woody species (MPTs) and/or animals as its component.
- Woody Perennials** : Normally multipurpose tree species, which has life span of several years (Perennials = plant species having life span three or more than three years).

1.8 SUGGESTED READING

Huxley, P. (1999). *Tropical Agroforestry*. Blackwell Science Ltd., Oxford, UK, 371 p.

Nair, P. K. R. (1993). *An Introduction to Agroforestry*, Kluwer Academic Publisher, 499 p.

Newaj, R. and Solank, K. R. (2000). *Krishivaniki ke Sidhant, Mahataw avam upiyogita*. Agrobios (India), Jodhpur, 194 p. (In Hindi) (In the book important notes are given in English also).

Singh, S. P. (1994). *Handbook of Agroforestry*, Agrotech Publishing Academy, Udaipur, 208 p.

Young, A. (1997). *Agroforestry for Soil Management*. 2nd Edn. CAB International/ICRAF, Wallingford/Nairobi, 288p.

1.9 MODEL ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

- 1) (a) False; (b) True; (c) True; (d) False; (e) True; (f) False; (g) True.
- 2) (a) Forestry; (b) Science, Non-woody; (c) Improvement; (d) Interacting.

Check Your Progress 2

- 1) a) arid, semi-arid and dry sub-humid; (b) 20 per cent; (c) wood, pulp; (d) Acacia catechu; (e) 160.
- 2) a) False; (b) True; (c) True; (d) False; (e) True; (f) False; (g) True.
- 3) a) Improve capture of rainfall and mineral nutrients.
b) Improve light, water and nutrient use efficiency of plants.

Check Your Progress 3

- 1) (a) Agri-silvicultural system; (b) Silvi-pastoral system; (c) Agri-silvi-pastoral system.

- 2) (a) Local, environment, plant species; (b) components; (c) Agri-silvicultural system; (d) Silvi-pastoral; (e) Agri-silvi-pastoral system (f) Agri-silvicultural.
- 3) (a) True; (b) False; (c) True; (d) True; (e) False; (f) True; (g) False; (h) True.

UNIT 2 AGROFORESTRY MANAGEMENT

Structure

- 2.0 Objectives
- 2.1 Introduction
- 2.2 Planning of Agroforestry Systems
 - 2.2.1 Components of Agroforestry
 - 2.2.2 Integration of Components
 - 2.2.3 Tree Crop Interface
 - 2.2.4 Land Consideration
- 2.3 Agroforestry Management
 - 2.3.1 Tree Management
 - 2.3.2 Intercrop Management
 - 2.3.3 Livestock Management
 - 2.3.4 Soil Fertility Management
- 2.4 Benefits of Agroforestry
 - 2.4.1 Environmental Benefits
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- 2.5 Role of Research and Extension in Agroforestry
 - 2.5.1 Research
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- 2.6 Let Us Sum Up
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2.0 OBJECTIVES

After going through this unit, you should be able to:

- get acquainted with management aspects of agroforestry in relation to tree, intercrop and livestock management;
- outline environmental and economic benefits emanating from agroforestry; and
- describe extension aspects of agroforestry.

2.1 INTRODUCTION

In the previous unit, definition, objectives, importance, concepts and potentials of agroforestry were covered. Distinction between agroforestry “system” and “practice”, agroforestry systems and practices and benefits of agroforestry as a land management unit were also dealt with.

Agroforestry has been a traditional practice in most parts of the country. Many traditional agroforestry systems have evolved over generations with modifications introduced by farmers from time to time. Examples of such systems are the multi-species spice gardens in Kerala and that based on Khejri (*Prosopis cineraria*) in Rajasthan. Not all combinations of species result in successful agroforestry systems. Planning of agroforestry requires bringing compatible species together and managing them in a manner that maximises their positive interactions and minimises the negative interactions.

Unlike systems in which a single crop is grown at a time, having more than one species in the field at the same time requires certain compatibility considerations. This is particularly so when the system comprises of perennial and annual crops. Besides, the species combination, fertility of land and moisture status for crop growth need to be considered in planning an agroforestry system.

In the next unit, diagnosis and design (D & D) exercise, PRA methods for choice of species and survey of multipurpose tree species were dealt with. You will also be exposed to indigenous traditional knowledge of agroforestry systems, shelterbelts and aqua forestry and the concepts of natural resource survey and economic consideration.

2.2 PLANNING OF AGROFORESTRY SYSTEMS

Agroforestry is a production system with more than one component species such as annual crops (e.g. wheat, groundnut), fruit trees (e.g. mango, amla), forestry trees (e.g. subabul, poplar) and animals (e.g. cattle, rabbit). Unlike plant species, permanent presence of animals is not required on the land under agroforestry. Sometimes, animals may never enter the land and their interaction with other components is indirect.

Complimentarity among these components is vital for the success of the agroforestry system. In an ideal agroforestry situation, there should be perfect harmony among the component species and all of them should benefit by growing together. Such a situation leads to higher output from each component as compared to when grown alone. Unfortunately, this seldom happens. Generally, one component dominates and as a result, the production of others in the system is adversely affected. The planning strategy for agroforestry systems should be to integrate the components in such a way that there is minimum competition among them and the maximum benefits are realised.

2.2.1 Components of Agroforestry

Agroforestry is a combination of agriculture and forestry. The agriculture component mainly consists of crop species grown for food (cereals, pulses, fruits, vegetables, spices) and agro-industrial raw material (cotton, sugarcane). Most of these crops are annuals or biennials, the exception being perennial fruit trees (mango, apple). The forestry component comprises of species producing fodder, fuel wood and timber. Almost all of them are perennial species and a majority of them are tall trees, but some are bushy in nature or are managed as short hedges by pruning. Agroforestry systems may have a combination of annuals and perennials (e.g. cereal-mango; sugarcane-poplar) or a mixture of only perennials (shade trees with coffee and cocoa).

Small farmers always prefer to produce some food on their farms. Therefore, they usually select annual food crops as a component of their system. It is also possible to have food production through the perennial component. Large trees like mango and relatively smaller ones like papaya are perennials producing food in an agroforestry system. Several agroforestry systems do not directly produce food. For example, silvipasture systems have trees with pasture grasses and legumes as the surface cover. In such a system, milk is an indirect produce.

The forestry component of agroforestry systems is usually the woody perennial species. The preferred perennials for this purpose are fast-growing multi-purpose species like subabul (*Leucaena leucocephala*) and poplar (*Populus deltoids*) that produce fodder, fuelwood and small timber. It is not necessary for the perennial component to be huge trees or to have a long lifespan. A majority of the perennials included in agroforestry systems are small to medium in size. Species such as *Sesbania sesban* that normally have life spans of about five years are successfully grown in agroforestry systems. In some systems, the perennial component is frequently pruned and maintained as a hedge instead of a tree.

The vegetation components in an agroforestry system can also be looked at from the size of the plants. Annual food crops are usually smaller in size compared to trees and are grown in the interspaces. Therefore, they are referred to as intercrops or understory crops whereas the perennial species are the overstory species.

Another component of agroforestry systems is farm animals. This does not mean that the animals should be permanently confined to the fields. This involves interaction with the crops and trees usually in the form of foliage used as fodder and animal waste returning to the field to enhance fertility.

The non-vegetation component of agroforestry systems consists of farm animals (cattle, goat) and birds (poultry, duck). This component is usually present in most of the crop farms in India, but there is no definite planning about their incorporation into the system. In a systematic agroforestry, this component is included with a well-defined role with operational details such as the number of animals / birds per unit of land and the period when they will be allowed into the field decided well in advance.

2.2.2 Integration of Components

Appropriate integration of components is absolutely essential for high productivity and maximizing returns and the eventual success of an agroforestry system. A well-integrated system possesses very high degree of complementarity among the components. Absence of integration results in competition with each other for environmental resources such as light, water and nutrients and low productivity. This competition occurs even among the plants of the same species. For example, in a stand of maize plants, every plant faces competition from other plants surrounding it. The leaves of adjacent plants shade each other and their roots inter-mingle, trying to absorb water and nutrients from the same soil. When the plants are of the same species and age, their leaves and roots would be almost same in size and the competition among them would be more or less equal. As a result, differences in growth or yield among the plants, if any, will be small. In an agroforestry system, on the other hand, the competition will be unequal because of the differences in the species. This leads to one species dominating the other, resulting in the suppression of the growth of the dominated species.

In an agroforestry system, trees have a tall and well spread out canopy shading the understory species. Similarly, their extensive root system can absorb water and nutrients to deprive the understory crops of their share. The competition is so uneven that a tree-based system left on its own will eventually become tree-dominated. Small farmers in certain cases would give priority to staple food items even at the cost of remunerative returns from trees.

Integration of the component species in a system should be such that it minimises competition among the species for environmental resources. Consequently, all the species in the system make a satisfactory contribution towards the production. Individually, the yield of a crop in agroforestry may be lower than that in a monocropped system. But the combined yields of all the component species in an agroforestry system should exceed the maximum production of each component.

2.2.3 Tree Crop Interface

The area of land where there is interaction between the component species of an agroforestry system is called the interface. If trees are planted far apart, the interface will be a circular area around the base of each tree (Fig.2.1). In systems where the trees are planted close to each other, usually in a row, there is overlapping of the interfaces of the trees. As a result, the interface becomes almost a strip on either side of the tree row (Fig.2.2). The width of this interface increases as the tree grows and may cover the entire field when the canopies of neighbouring trees touch each other.

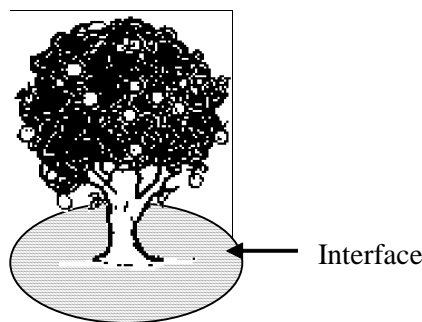


Fig.2.1: Interface of a tree

The interface is also the area within which the micro-environment is modified by the canopy of the overstory species. The obvious change is the reduction in the light. In addition, the presence of trees reduces evapotranspiration, air temperature, soil temperature and wind speed. Most of these changes are beneficial to annual crops. These benefits are more than offset by competition for water and nutrients below the ground and light above the ground.

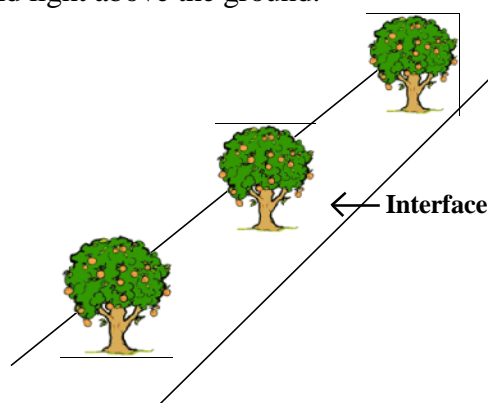


Fig.2.2: Interface as a strip

The relationship between the component species within the interface may be positive or negative (Fig.2.3). A positive relationship where both species benefit does not occur that often. This requires the tree species to have a thin canopy that allows adequate light to penetrate through for the intercrops. In addition, the roots of the component species should occupy different strata of soil in order to avoid competition for moisture and nutrients. Unfortunately, this does not happen that often in actual field conditions. The ideal tree-crop combination is one in which the tree has a thin canopy with a root system that grows deep without much lateral spreading and the intercrop is shade tolerant with a shallow root system.

The commonly found relationship in the interface is one where atleast one species shows a negative effect. Usually, the intercrop suffers due to competition from the perennial component. The interface can be easily recognised in this case as it is the area where the growth of the intercrop is affected. The growth of the intercrop usually shows a gradual increase as the distance from the base of the tree increases. Some intercrops, such as aggressive grasses in silvi-pasture systems, can be the dominant partners of the system, reducing the growth of trees. There are also situations of both the perennial component and the intercrops suffering due to competition in the interface.

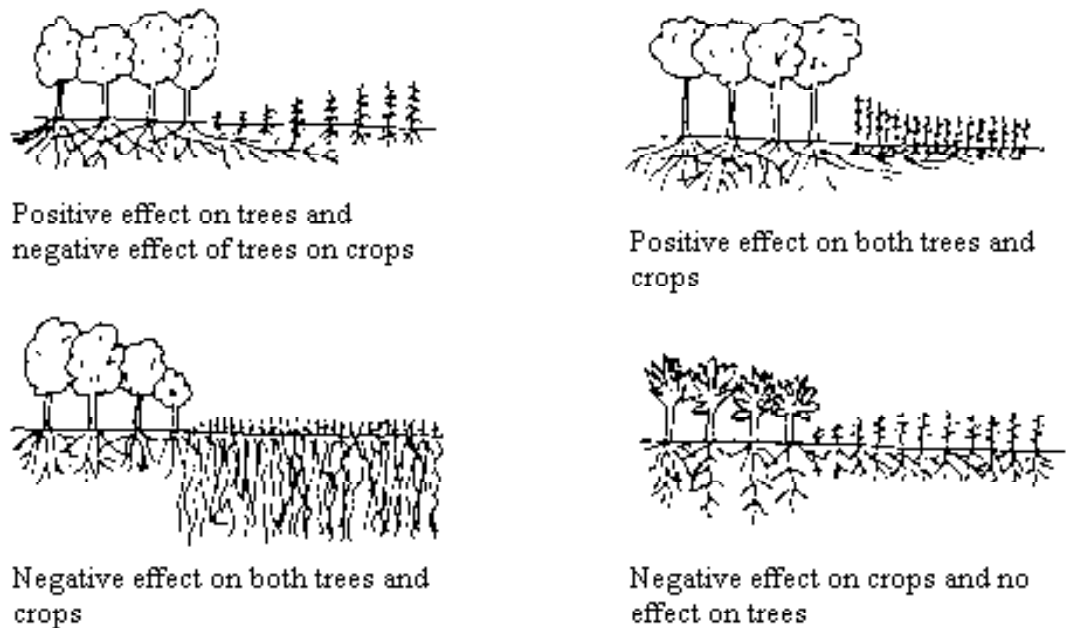


Fig.2.3: Relationships in tree-crop interfaces (Source: Agroforestry Systems)

The area of land under the tree-crop interface is determined mainly by the following factors associated with the tree component: (a) age, (b) number per unit area of land and (c) planting arrangement. The canopy and root system of trees grow with age and occupy more and more land. The presence of the tree is hardly felt by the other crops in the system during the first year and possibly the second year. Thereafter, the area influenced by trees, mostly in the form of competition, increases. Interface increase due to age cannot be changed, but that resulting from number and arrangement can be modified. The interface area increases when there are more trees in a unit of land. If this has to be avoided, fewer trees should be planted. In case they are already present in the field, selected trees can be removed to reduce the pressure on intercrops.

The third factor, arrangement of trees in the field, is an important consideration in reducing the interface area in agroforestry systems. For example, 100 trees are planted in one ha area at a spacing of 10 x 10 m. When the trees grow, interaction among them will be the least because the branches and roots of each tree has at least 5.0 m to grow in each direction before it encounters the adjacent trees. As a result, interaction among the trees is low, but the tree-crop interface is high. On the other hand, if the trees are planted at the spacing of 5.0 x 20 m, the interaction between adjacent trees is high because each tree has only 2.5 m in one direction before it encounters its neighbour. In the other direction, however, the distance available is 10 m; most agroforestry trees seldom grow this far in one direction, so the interface area is low. Crops are grown in this space between two tree rows.

Thus, the area of interface between trees and crops in an agroforestry system can be determined by selecting the appropriate spacing and plant population of the trees. This is decided based on the competition on the intercrop, the economic value of its produce and the ecological benefits it brings to the system.

2.2.4 Land Consideration

Knowledge about the type of land is necessary for planning an agroforestry programme. Agroforestry systems can be introduced on any land. However, the prospect of yield reduction of food crops should be an important consideration if fertile land is to be brought under agroforestry. In states like Punjab and Haryana, systems based on poplar tree have been very successful with crops like wheat, rice and sugarcane. The agricultural crops in these systems do not experience a drastic reduction in yields because of favourable soil fertility conditions, availability of water and the compatible nature of poplar.

In conditions where water is a limiting factor, trees can suppress the growth of annual crops. Therefore, on fertile lands in dry areas where the present systems with annual crops produce reasonably good yields, agroforestry may not be a desirable option. If agroforestry is taken up on marginal lands totally dependent on rainfall where the present yield levels are very low, the reduction in crop yields will be more than compensated by the returns from the trees. Moreover, having such land under trees can also improve its fertility. Hence, agroforestry is a suitable system for marginal lands.

Check Your Progress 1

Note: a) Use the space below for your answers.

b) Compare your answers with those given at the end of unit.

- 1) What are different components of agroforestry? Name the important species comprising these components.

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- 2) What is meant by tree-crop interface? Explain positive and negative relationship of this interface.

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2.3 AGROFORESTRY MANAGEMENT

2.3.1 Tree Management

Trees in an agroforestry system may be horticultural crops (e.g. mango, cashew) or forestry species (e.g. neem, subabul). Newly planted trees do not compete with annual crops; competition begins in about the second year and continues to increase with time. If trees are planted at a distance of more than 10 m, not more than 25 per cent of the land will be lost to tree interface during the first five years. Hence, annual food production will not suffer significantly. In small farms operating at very low levels of inputs, increasing the yield of annual crops in the remaining land can more than compensate for the reduction in land area. This can be achieved through the introduction of new crop varieties, increased inputs and following improved management practices.

Eventually, however, trees begin to dominate the system which is reflected in declining crop yields. If the tree species is a horticultural crop like mango, competition becomes evident by about the time they start producing fruits. As the loss from one crop is compensated by the returns from another, farmers may not be unduly worried at this stage. But farmers become apprehensive when the crop loss due to competition becomes pronounced in subsequent years. In agroforestry systems where the perennial component is a fast growing multi-purpose tree, competition starts early, sometimes in the second year itself. Whether the competing perennial is a fruit tree or a multi-purpose tree, farmers have to start managing their tree canopy at some point of time.

2.3.2 Intercrop Management

The management requirements of each crop in an agroforestry system are specific. They have to be addressed separately for the system to be successful. In perennial-annual systems, the intercrops have certain disadvantages because they are the understory species. Their main limitation is the competition for light, water and nutrients from the perennial species. In planned agroforestry, care is taken to minimise the competition by having the trees planted at wider spacing. This may result in fewer trees per unit area of land than recommended, but the returns from the intercrops will more than compensate the loss in the perennials.

Depending upon the growth rate of the trees, the competition from trees will be minimal during the first 2-5 years. Therefore, the reduction in annual crop yield will be less than 20 per cent of what can be harvested when they are grown as sole crops. This is an affordable loss to most farmers, considering the benefits that will be realised later on from the trees. Eventually, however, the intercrops will face competition from the trees and therefore their management becomes important to minimise their yield loss. In the interface, competition for light under

the shade of the perennial species is inevitable. Selection of shade tolerant species like tumeric is a possibility, but their soil and climatic requirements should also be satisfied.

In the absence of such species, the practice of farmers is to leave an uncropped band of 2.0-4.0 m on either side of the tree row which means unavoidable reduction in the area under the annual crop. Besides the competition factor, the intercrops can also be saved from dripping rainwater by not planting them directly under the tree canopy. In the remaining area, the intercrop should receive the optimum management to maximise the yield. The main requirement here is to apply fertiliser or manure and irrigate the crop as per normal recommendations. Crop protection measures against pests and diseases should also be carried out regularly. The species susceptible to the same pests and diseases as the perennial component in the system should not be selected as intercrops. Regular weeding is necessary as unlike the perennial species, the intercrop is susceptible to competition from weeds.

In certain cases, intercrops such as pasture grasses and sugarcane become very aggressive adversely affecting the growth of the perennial species. This is particularly so in the case of young fruit trees. In such situations, it is necessary to uproot the intercrops growing close to the perennials to protect the young saplings. Sometimes, land under well-established trees may be converted into agroforestry by growing crops in the interspaces. This usually happens when intercropping is initiated in a fruit orchard or community wood lot.

Under these conditions, the existing tree population may be such that shading cannot be avoided. Therefore, very little can be done to create favourable conditions for the intercrop and its yield might be considerably lower as compared to its potential. However, returns from the intercrop are an additional benefit to income from the trees. Therefore, management options are limited to reduce the competition for environmental resources and increase the intercrop yields.

2.3.3 Livestock Management

Livestock, especially small animals, can be included as a component of agroforestry systems. They do not have to be permanently in the field. Depending upon their management, (a) animals may permanently remain on the field, (b) temporarily let in for grazing or (c) never enter the field as is the practice in stall-fed systems. In silvipasture systems, land may not be a constraint, so the animals are allowed to graze and stay in the field itself. The stocking rate, that is, the number of animals per unit area of land, has to be adjusted to prevent overgrazing of the field. The field may also be partitioned into paddocks and the animals moved from one enclosed area to another. There is hardly any opportunity to practice this type of system in India because of the pressure on land.

A common practice in most parts of the country is to allow the farm animals to graze on cropland soon after the crop is harvested. The leftover residue after the harvest of the crop is an excellent fodder. In addition, grass growth, if any, also becomes fodder. This practice can also be adopted in agroforestry after the tree canopy grows beyond the reach of farm animals. In agroforestry systems with annual crops, soon after the harvest of the intercrop, the interspaces will be littered with residue. Allowing the animals at this stage will benefit the animals as they get valuable fodder. At the same time, the fertility of the land gets enhanced

by the dung and urine of the animals. Pruning from the trees can also be fed to the animals.

There can be agroforestry systems where a farmer has livestock, but the animals are permanently separated from the farmland. This can happen when the animals are stall fed and never allowed to graze directly on the land. The interaction between the animal and the land is similar in this system as fodder is exchanged for dung and other farmyard waste. However, the transport of fodder and dung has to be done by the farmer requiring additional labour. There may be situations where the fodder and other biomass residue are taken out of the land, but the dung and farmyard waste are not returned. If this is continued for long, the fertility of the land can get depleted over a period of time.

2.3.4 Soil Fertility Management

In dry tropical areas, soil fertility is a major consideration in deciding which land is to be brought under agroforestry. Large farmers have the resources and ability to manage the fertility of their land better than the smallholders. They can afford to set aside a portion of the farm for rehabilitation for a season or two. During this period, green manure crops can be grown on this land and the foliage ploughed in. It is also possible for large farmers to buy organic manures in large quantities and apply to the land to improve the fertility.

Small farmers, however, do not have these options as they have to crop their land every season to earn their livelihood. If their land fertility is satisfactory and irrigation water is available, it is better for them to adopt a cropping system comprising of only annual crops. Agroforestry is an option for lands where high returns cannot be obtained with annual crops because of fertility and irrigation constraints. On such lands, agroforestry together with a well-planned fertility management programme can result in satisfactory yields from the annual crops as well as trees. More importantly, the practice of agroforestry gradually improves the soil fertility.

Soil fertility improvement is a very slow process and takes a considerable time to yield results. This has been well demonstrated in alley cropping, an agroforestry system, where the biomass from multipurpose trees is required to be incorporated into the soil as green manure. The soil fertility improvement in response to this practice is so slow that farmers do not feel it is worth continuing. Consequently, farmers tend to use the biomass as fodder, which yields an immediate response in the form of increased milk yield. The purpose of agroforestry for soil fertility is lost due to this practice and the land quality may even become poorer than what it was at the time of agroforestry introduction.

Soil fertility management under agroforestry systems has to take into account the prevailing land quality and the individual nutrient requirements of constituent species in the system. Agroforestry improves the fertility as trees add organic matter to the soil in the form of fallen litter and root decay. Moreover, commonly grown agroforestry trees like *Leucaena leucocephala* and *Gliricidia sepium* fix biological nitrogen, which improves the soil nitrogen status. The soil fertility management practices for these lands include incorporation of fallen litter into the soil, minimum tillage to reduce soil disturbance and prevention of excessive drying by the use of mulch. If fodder is continuously harvested and taken away from the land, there should be some compensation in the form of organic manure application.

In agri-horticulture systems, the nutritional requirement of fruit trees and annual crops has to be taken care of independently. Manure or fertiliser for fruit trees can be applied in a basin around the base of the tree and for the annual crops, it can be broadcast or given as a band. Fast-growing multipurpose trees are not usually fertilised, but their roots may grow towards the root zones of the other species in the system and compete with them. Ploughing the area demarcated for annual crops can to some extent clip the roots encroaching into the area, but total protection is impossible.

Activity 1

Visit agroforestry farms and examine the planning and management aspects in practice. Document these practices together with your observations to improve them.

Check Your Progress 2

Note: a) Use the space below for your answers.

b) Compare your answers with those given at the end of unit.

1) Describe the role of tree management in agroforestry.

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2) What is intercrop management in agroforestry.

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3) Explain the role of livestock in agroforestry.

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Now that you have done the Check Your Progress 2, we may study important benefits of agroforestry.

2.4 BENEFITS OF AGROFORESTRY

2.4.1 Environmental Benefits

Environmental degradation is posing a serious challenge to the very survival of the mankind. Deforestation combined with emission of gases from modern gadgets, machines and automobiles has resulted in ecological imbalance in the form of

global warming and climate change (due to increase of CO₂ in the atmosphere), recurring droughts and floods, serious soil losses and pollution. Concerted efforts need to be made to restore the ecological balance by increasing forest cover and maintaining the existing forests and sanctuaries. Trees help check erosion, land slides and reclaiming wasteland. This in turn would greatly check sedimentation of our reservoirs. Afforestation on roads, rails and canals improves microclimate and environment. Continuity of plant cover, utilization of solar radiation, capacity to enrich soil and modification of microclimate are the important characteristics of trees selected for environmental protection. Protecting environment has assumed a considerable significance in the present context of large scale pollution and climate change. As a consequence, more and more area is coming under national parks and sanctuaries. Besides, restriction on uprooting of green trees and other measures, availability of timber is declining encouraging farmers to adopt afforestation of waste lands and planting of trees on farm lands and on sides of rails, railway tracks and canals.

2.4.2 Economic Benefits

Economic issues play an important role in deciding agroforestry system. Demand, supply, land use policies, market forces etc., are the important factors in the selection of agroforestry systems. Even in the recent past, agriculture received the highest priority even at the cost of the existing trees. However, fruit trees were generally retained. Agroforestry has now assumed a considerable importance in view of its complimentary role in raising/supplementing farm income, adding nutrition to the land and improving environment. Besides economic considerations, social, cultural and ecological implications have to be kept in view in agroforestry. Following factors need to be considered for economics of agroforestry system.

a) Land –Man Ratio

India has about 2 per cent land resource to support 15 per cent of human 16.5 per cent of the livestock population and per capita land area is one of the lowest in the world. In view of the largest number of persons actively engaged in agriculture, land- man ration is very small. Most of the land holdings in India are small about two-area is still rainfed. Majority of the small and marginal farmers are not able to divert their land for any other purpose as agriculture sustains them.

b) Shortage of wood and steep price rise

The demand for food, fodder, wood and other products has increased considerably over the years due to ever growing population. The forest area has decreased drastically due to its diversion to agriculture and other uses. As a result, price of forest products has steeply increased. The prices of agricultural commodities have the increased 3 to 5 times over the past 25 years as against 15-20 fold increase in the forest produce. Therefore, tree plantation particularly fast growing species has become a beneficial option.

c) Wood Consumption Pattern

There has been a marked increase in the consumption of commercial and industrial wood for paper, plywood, furniture etc. as a result of improvement in living standards. There is acute scarcity of firewood demand. These factors have led to steep increase demand of wood.

d) Policies

Government policies contribute to the growth of agroforestry in a big way. The Forest Policy aims to ensure the environmental stability and ecological balance. The farmers particularly, small and marginal farmers need to be encouraged to grow wood species for industries on marginal lands by providing incentives.

e) Marketing

In case of wood and fodder, no price control mechanism exists due to which farmers are exploited by the industrial sector. Non availability of storage facility, poor accessibility and high transportation cost act are the main factors which discourage the farmers to go for agroforestry. The underdevelopment of wood markets contributes of low price to the producers and still high price paid by the consumers.

f) Time Span

In a large number of agroforestry systems, the output is obtained after several years which acts as a disincentive to the farmers due to the risks involved during this period in addition to non-existence of demand at the end of the growth period.

g) Risks

Trees are long duration crops and returns and prices may fluctuate. Marketing infrastructure for wood is not well developed.

Agroforestry systems provide material and services where services refer to sustainability as well as environmental value. Sustainability of the system is attributed to biological nitrogen fixation, nutrient cycling, green manuring, contour planting etc. These services cannot be evaluated in economic terms. The valuation of material outputs such as fuelwood, fodder, timber etc. will be different with regard to public and private economies.

Economics of Individual systems

Agroforestry systems vary a great deal with regard to their crop composition, ecological interaction, labour requirement, investment and nature of returns. Different systems have different components. In trees dominated systems, it is ecologically safer; the investment is made in the initial year and returns are expected after a long period. In annual crop dominated systems, investments and returns are of annual nature. Economic considerations in different agro-agroforestry systems are discussed as follows.

i) Shifting Cultivation

The system operates at subsistence level and in these areas, land is adequate and labour is scarce and transport and market facilities are not developed. There is no demand for tree products which are used only for household purpose. Though the system works efficiently both economically and ecologically, economic evaluation of the system is lacking.

ii) Taungya System

It refers to a system where a forest crop is established along with agricultural crops. The cultivators are allowed to grow agricultural crops and in return they

have to raise forest crops. Thus the system involved intensive use of land and was thus popular where land was scarce and people were poor. The system appears to be exploitive and therefore it is no longer practiced in large areas. The farmers therefore need to given additional benefits and their health, sanitation, education etc. of the cultivators looked after.

iii) Agrisilviculture Systems

Trees on agricultural land; trees with plantation crops; home gardens; village wood lots; alley cropping etc. are common agrisilviculture systems. It is difficult to work out economics of these systems as the correct information on inputs and outputs is not available.

Growing trees on farm land in various geometry and scattered patterns (blocks, rows or strips or boundaries) is the most common agrisilviculture system. The economics depends on species mix, duration of the association and other physical and biological factors. A few trees grown in scattered form are meant for household use and do not produce enough for marketing. In large parts of the country, farm forestry (trees generally grown on field bunds such as eucalyptus, teak etc.) was met with great success due to low labour input and other factors initially but lack of sound marketing system led to steep decline in returns from tree farming and hence loss of interest.

Tree grown with high value crops such as tea, coffee, rubber, coconut etc. not only result in high returns due to production of timber and firewood but provide needed shade to these crops.

In home gardens, besides growing trees, vegetables, fruits and other useful crops grown in a small area (less than 0.1 ha) around village house, other miscellaneous activities such as storing hay, making livestock pens, rearing poultry etc. are also carried out. Per unit production in home garden is the maximum among various agroforestry systems.

Live fence of thorny species such as *Acacia nilotica*, *Carissa spinarum* etc., is not only effective in protecting the crops from damage by stray animals etc., but also provides firewood and fodder.

iv) Silvipasture and Pastural Silviculture

These systems comprising of fodder grasses and fodder trees provide fodder, firewood and timber. The fodder production per unit area from these systems is reported to be higher than the production from fodder grasses alone. Not much work on economics of this system is reported, however, some initial studies indicate that these systems are economical as compared to simple pasture management.

2.5 ROLE OF RESEARCH AND EXTENSION IN AGROFORESTRY

Adoption of effective agroforestry programmes will go a long way in addressing food, wood, employment and environmental problems. Integrated multidisciplinary approach is quite effective for systematic development of agroforestry system. Lack of trained manpower in agroforestry at different levels is one of the serious

constraints for promoting agroforestry. It is therefore, essential to undertake research on different aspects of agroforestry and transfer of need based and cost effective technology through training and other extension techniques.

2.5.1 Research

On-station research in different agro-climatic zones is of vital importance for selection of appropriate species of trees and adoption of techno-economical agroforestry system in order to increase income as well as for maintaining soil fertility, conserving soil moisture and reducing soil erosion problems. In order to realize the desired results from the developed technology, the technology needs to be tested at the farmers’ fields to identify the gaps between the controlled research and actual field conditions and also to build confidence in the farmers for the technology.

2.5.2 Extension and Training

Agroforestry is a complex system requiring multidisciplinary approach which poses a challenge to the extension workers for popularizing the technology. Various agroforestry systems depending on agro-climatic conditions of the regions need to be propagated by using innovative extension techniques. Training is one of the most important extension techniques for refreshing and upgrading the skills of the extension workers and the farmers. This leads to effective dissemination of knowledge and skills. Training in agroforestry not only helps motivate the farmers and create confidence in them to adopt latest technologies but also upgrades the knowledge and skills of the trainers for effective dissemination of technology among the farmers. It is therefore, necessary to train persons engaged in extension work as well as the members of the target group. Training methodology, contents, technical know-how etc. need to be developed depending on the level of the extension worker. Training of the target groups should be conducted in two phases, i.e. before implementation of the programme and second after implementation of the programme. The first phase may include best suitable technologies for solving biophysical and socio-economic problems and evaluation of impact of training while second phase may involve transfer of technology at the farms under the supervision of the extension workers, the problems encountered during adoption of technology, modification of technology as per need and impact of training on the adoptability of the programme. Krishi Vigyan Kendras (KVKs), and Farmers Training Centres play an important role in conducting these training and programmes. Besides, special agroforestry camps need to be organized at the block and district levels as per the need of the farmers.

Check Your Progress 3

Note: a) Use the space below for your answers.

b) Compare your answers with those given at the end of unit.

1) Enumerate environmental and economic benefits of agroforestry systems.

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2) Describe the role of extension and training in promoting agroforestry..

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3) List factors to be considered for economics of agroforestry systems.

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2.6 LET US SUM UP

- Planning and management of agroforestry aims at introducing systematic and intensive systems in order to increase productivity and ensuring improved soil fertility and increasing crop diversity. The compatibility among the component species is extremely crucial for the success of the system.
- The management of complex agroforestry systems is largely dependent on the optimization of both ecological and social processes.
- Agroforestry is a combination of agriculture and forestry. The agriculture component consists of generally annuals or biennials crop species grown for food (cereals, pulses, fruits, vegetables, spices) and agro-industrial raw material (cotton, sugarcane) and the forestry component comprises of species producing fodder, fuel wood and timber.
- Appropriate integration of components is absolutely essential for successful agroforestry system resulting in high productivity and maximizing returns and the eventual. Lack of integration leads to competition with each other for environmental resources and low productivity.
- Selection of appropriate spacing and plant population (interface) of the trees based on the competition on the intercrop, the economic value of its produce and the ecological benefits is absolutely essential for successful agroforestry.
- Agroforestry on marginal lands not only compensates very low productivity of crops by returns from trees but also improves soil fertility.
- Management of tree canopy in case of both perennial fruit and multi-purpose tree is absolutely essential to minimize the negative impact of competition. In planned agroforestry, the trees are planted at wider spacing and the return from the intercrops adequately compensates the loss in the perennials. Livestock management and soil fertility management are important aspects of successful agroforestry system.
- Environmental degradation is threatening the agricultural sustainability and human survival. Agroforestry plays an important role offsetting the negative effects of growing pollution resulting in global warming and climate change.

Besides, agroforestry has a very important role in raising/supplementing farm income and adding nutrition to the land.

- Trained manpower in agroforestry at different levels is necessary for promoting agroforestry. Training on multidisciplinary aspects of agroforestry is of paramount importance for refreshing and upgrading the skills of the extension workers and the farmers for effective dissemination of technology

2.7 KEYWORDS

Gliricidia sepium	:	Fast growing nitrogen fixing tree used to provide shade to shade loving crops.
<i>Khejri (Prosopis cineraria)</i>	:	A wonder tree also known as the 'king of desert' checks the deserts, boosts economy of the desert area and rich in medicinal value.
<i>Leucaena leucocephala</i>	:	Leucaena species are grown for variety of uses, including as green manure, a charcoal source, livestock fodder, and for soil conservation. <i>Leucaena leucocephala</i> have edible fruits (as unripe) and seeds.
Overstory species	:	Consist of giant emergent trees that tower above the surrounding canopy.
Paddocks	:	A small field near a house or stable with grazing for horses.
<i>Sesbania sesban</i>	:	Important fast growing agroforestry species used for fuel wood and fodder and can tolerate saline and waterlogged conditions.
Silvipasture	:	Refers to grazing of livestock and growing of trees on the same piece of land and can be developed by establishing trees in existing pastures or by establishing pastures within or under existing tree stands.
Stall Fed	:	A compartment in a building where a single large animal (s) lives or is fed or milked.
Subabul	:	A large, evergreen, fast-growing shrub or a small tree.
Understory species	:	Crops or species planted under forest, orchard, or other trees such as vines, shrubs, herbaceous plants, or shorter trees. When integrated with tree crops, they can provide earlier returns and diversify farm yields.
Woodlot	:	A privately owned tract of woodland where trees are grown for fuel, posts, timber, or pulpwood.

2.8 SUGGESTED READING

Jose, S. and Gordon, A. M. (2008). *Toward Agroforestry Design - An Ecological Approach*. Springer Publishing Company, Berlin.

MacDicken, K. G. and Vergara, N. T. (1990). *Agroforestry: Classification and Management*. Wiley-Interscience Publication, John Wiley & Sons, USA.

Nair, P.K.R. (1993). *An Introduction to Agroforestry*. Kluwer Academic Publishers, Utrecht, The Netherlands.

National Research Centre for Agroforestry (2004). *Fifteen Years of Research (1988-2003)*, NRCAF Publication, Jhansi, India.

Tejwani, K. G. (1994). *Agroforestry in India*. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, India.

2.9 MODEL ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

- 1) Agroforestry consists of agriculture and forestry components. The agriculture component mainly consists of crop species grown for food (cereals, pulses, fruits, vegetables, spices) and agro-industrial raw material (cotton, sugarcane) whereas the forestry component comprises of species producing fodder, fuel wood and timber.
- 2) Interface refers to the area of land where there is interaction between the component species of an agroforestry system. The relationship between the component species within the interface may be positive or negative. A positive relationship where both species benefit, requires the tree species to have a thin canopy that allows adequate light to penetrate through for the intercrops. In the interface, at least one species shows a negative effect. Generally, the intercrop suffers as a result of competition from the perennial component.

Check Your Progress 2

- 1) In agroforestry systems, tree management is necessary when the crop loss due to competition between crop and trees becomes considerable after a few years. In case of the perennial component being fast growing multi-purpose tree, competition starts early, sometimes in the second year itself. Whether the competing perennial is a fruit tree or a multi-purpose tree, farmers need to manage their tree canopy at some point of time.
- 2) In perennial-annual systems, the intercrops being understory species result in the competition for light, water and nutrients from the perennial species. In planned agroforestry, it is managed by planting trees at wider spacing. This may result in fewer trees per unit area of land than recommended, but the returns from the intercrops will more than compensate the loss in the perennials.
- 3) The role of livestock in agroforestry systems is complementary. Animals get valuable fodder from annual crops even after the harvest of the intercrop and

at the same time, fertility of the land gets enhanced by the dung and urine of the animals.

Check Your Progress 3

- 1) Agroforestry has an important role to play in maintaining ecological balance, checking serious erosion and land slide problems and providing timber and products as well supplementing income of the farmers. Afforestation on roads, rails and canals improves microclimate and environment by reducing CO₂ content and eventually global warming responsible for climate change.
- 2) Various agroforestry systems depending on agro-climatic conditions of the regions need to be propagated by using innovative extension techniques. Training is one of the most important extension techniques for refreshing and upgrading the skills of the extension workers and the farmers.
- 3) Following factors need to be considered for economics of agroforestry system.
 - Land –Man Ratio
 - Shortage of wood and steep price rise
 - Wood Consumption Pattern
 - Policies
 - Marketing
 - Time Span of growth
 - Risks

UNIT 3 SURVEY AND DOCUMENTATION OF EXISTING PRACTICES (PRACTICALS)

Structure

- 3.0 Objectives
- 3.1 Introduction
- 3.2 Diagnosis and Design Exercise
 - 3.2.1 Prediagnostic Stage (Steps 1-3)
 - 3.2.2 Diagnostic Stage (Steps 4-6)
 - 3.2.3 Technology Design Stage (Steps 7-9)
 - 3.2.4 Follow-up Planning Stage (Stage 10-12)
 - 3.2.5 You Can Do It
- 3.3 Participatory Rural Appraisal (PRA) for Choice of Species and Need
 - 3.3.1 Transect Analysis
 - 3.3.2 Mapping
 - 3.3.3 Seasonality Diagram
 - 3.3.4 Ranking and Scoring
 - 3.3.5 You Can Do It
- 3.4 Survey of Multipurpose Tree Species (MPTS) and their Uses
 - 3.4.1 Fodder Tress
 - 3.4.2 Fuel Wood Trees
 - 3.4.3 Fruit Trees
 - 3.4.4 Other Woody Perennials
 - 3.4.5 Procedure for Survey of Multipurpose Tree Species/Shrub Species (MPTS)
 - 3.4.6 You Can Do It
- 3.5 Indigenous Agroforestry Systems, Indigenous Knowledge, Shelterbelts and Aquaforestry
- 3.6 Concept of Natural Resource Survey and Economics
 - 3.6.1 Concept of Natural Resource Survey
 - 3.6.2 Economic Consideration
- 3.7 Let Us Sum Up
- 3.8 Keywords
- 3.9 Suggested Reading
- 3.10 Model Answers to Check Your Progress

3.0 OBJECTIVES

After going through this unit, you should be able to:

- enumerate various steps for diagnosis and design (D & D) exercise and conduct field exercise;

- describe PRA methods for choice of species and needs and conduct field exercise;
- describe the procedure for survey of multipurpose tree species;
- get acquainted with indigenous traditional knowledge of agroforestry systems;
- explain shelterbelts and aqua forestry; and
- understand the concepts of natural resource survey and economic consideration in context of agroforestry.

3.1 INTRODUCTION

In the previous unit, management aspects of agroforestry in relation to tree, intercrop and livestock management, environmental and economic benefits emanating from agroforestry and extension aspects of agroforestry were covered.

Agroforestry represents an integrated land use approach involving deliberate retention or admixture of trees and other woody perennials in crop/animal production fields to benefit from resultant ecological and economic interactions. In fact, due to its multifaceted dimensions, agroforestry has acquired wide acceptability. Agroforestry broadly has two main objectives: productivity (involving multitude of outputs) and sustainability (which implies conservation, or even improvement, of the environmental aspects of the system).

Though, a large number of agroforestry systems have been practiced but they deal with only a few agroforestry practices. It is very important to get acquainted with the agroforestry approaches with emphasis on practical aspects. Various tools and methodologies currently being used to document existing or traditional agroforestry practices or systems that have evolved under site specific conditions need to be studied. Important features of some existing agroforestry practices/systems common in certain parts of India will also be discussed.

3.2 DIAGNOSIS AND DESIGN EXERCISE

Considering the potentials of agroforestry and lack of quantitative methods to evaluate agroforestry systems, it is important that widely adoptable methodologies are developed for evaluating the systems. Diagnosis and Design Exercise, commonly referred to as D & D exercise was developed at World Agroforestry Centre (formerly ICRAF), Nairobi, Kenya in 1980s to document the existing agroforestry system of a particular location and then to design appropriate agroforestry project for similar site conditions (Raintree 1987).

One of the major principles underlying D & D methodology is derived from an analogy with medicine i.e., diagnosis should precede treatment. It means that actual needs and potential of existing land use system should be documented before designing any agroforestry land use system for a particular site. Here, design means development of appropriate agroforestry approach for the land use system, where diagnosis has already been carried out. Thus, D & D exercise has essentially two major parts. Firstly, diagnostic exercise is conducted by a multi-disciplinary team of research workers of the field of forestry, agriculture soil science, climatology, geography, socio-economic, etc. which takes about two weeks. This is followed by development of appropriate design concept for

agroforestry interventions to improve existing land use. It takes two to four months to arrive at certain logical conclusions about design to be implemented. Once, theoretically a design is created, a smaller working group refines the design as per needs of stakeholder(s) and potential of land use (by further quick validation and interpretation of data gathered during diagnostic survey). Development of the detailed project implementation plan is the final step. This type of D & D application is designed to economize time and manpower and make best use of available limited resources.

D & D exercise consists of a series of information gathering and analytical steps, leading logically from one to next (Huxley 1983). The sequence entails a hierarchical progression from general to the particular to develop progressively sharper focus on essential information. The whole exercise is thus divided into following four stages consisting of twelve steps:

3.2.1 Prediagnostic Stage (Steps 1-3)

It covers (1) background description of the study area, including relevant aspects of biophysical and socio-economic environment; (2) differentiation and selection of land use system within the study area; and (3) preliminary description of diagnostically relevant aspects of selected system.

3.2.2 Diagnostic Stage (Steps 4-6)

It includes (4) diagnostic survey of selected system and relevant aspects of environmental settings; (5) diagnostic analysis and identification of major land use problems and potentials; and (6) derivation of specification for appropriate technology (including non-agroforestry options but with special attention to agroforestry potential).

3.2.3 Technology Design Stage (Steps 7-9)

It involves (7) selection of candidate technologies for inclusion in design; (8) synthesis of general design concept for an improved land use system; and (9) evaluation and refinement of the proposed design.

3.2.4 Follow-up Planning Stage (Steps 10-12)

This stage covers (10) identification of research needed to develop or test identified agroforestry technology; (11) identification of areas needing further D & D attention in a follow up stage; and (12) development of detailed project implementation plan to carry out envisaged R & D programme.

The whole process is carried out in participatory mode to maximum possible extent. It is illustrated by an example of Bambore-Baorli Watershed (Jodhpur district, Rajasthan) agroforestry system (Table 3.1). First three phases of D & D exercise deal with information collection and designing the appropriate agroforestry intervention in target area. However, fourth phase i.e., follow up planning stage involves both on 'research station' research through experimental investigation of fundamental aspects of proposed technological interventions, as well as on 'site research' through *in situ* trials of candidate 'technological package' on target area. The experimental *in situ* trials provide ample opportunity for continuing diagnosis and refine the proposed project design for best management of target area.

Table 3.1: Site summary of Agroforestry Diagnosis and Design (D & D) indication of a watershed in arid western Rajasthan **Survey and Documentation of Existing Practices (Practicals)**

Prediagnostic Stage (Steps 1-3)		Diagnostic Stage (4-6)	Technology Design Stage (Steps 7-9)	Follow up Planning Stage (10-12)
Site Details	System description			
<p>Area: Bambore-Baorli Watershed</p> <p>Location: 39 km north-west of Jodhpur town, Jodhpur</p> <p>Villages: Bambore- Baorli and Tulesar</p> <p>Total Area: 870 ha</p> <p>Total households: 138 (nos.)</p> <p>Total human population: 1417</p> <p>Total Livestock: 1392 animals (goats 57%, cows 17%, buffalo 9% and others 22%)</p>	<p>Climate: Arid, average total annual rainfall 300 mm</p> <p>Soils: Sandy and sandy loam</p> <p>Farming System: Mixed, crop-livestock (in true sense traditional agroforestry system); <i>Prosopis cineraria</i> trees are found scattered on crop fields; density = 16 trees/ha)</p> <p>Crops: Pearl millet, mung bean, moth bean, clusterbean and sesamum (all rainfed)</p> <p>Economy: Subsistence farming</p> <p>Area available for cultivation: 620 ha</p> <p>Average cultivable land per household: 4.5 ha</p>	<p>Some important aspects of environmental setting of the site: North and north-eastern part of watershed is bounded by a rocky chain of hillocks with slope of 18-26%. Two ephemeral streams originate from hilly region and these streams are source of water for two village ponds. Majority of agricultural lands in watershed are located in lower flood plains. Traditional extensive agroforestry system has been practised in the area since ages and it is khejari (<i>P. cineraria</i>) based. Some other tree species are also found scattered on crop fields. Tree species provide fuel and fodder to villagers.</p> <p>Problems in basic needs supply</p> <p>Food: Below average rainfall, that too quite erratic and droughts are very common. Shortage of stable food; must purchase during drought years; low milk production; livestock mortality during drought years; lack of knowledge about proper livestock care.</p> <p>Fodder: Acute shortage of fodder during drought years; Even during low rainfall years there is fodder shortage; In general trees on crop lands provide 20-</p>	<p>Selection of candidate technology: On the basis of problems identified, best-technology options area:</p> <ul style="list-style-type: none"> • Strengthening tree component in traditional agroforestry system by incorporating fast growing and well adaptable fuel and fodder trees on crop lands. • Utilizing drought tolerant high yielding crop varieties. Always better to introduce dual purpose (food grain & fodder yielding) varieties. • Living fences of high yielding fuel wood species and fruit producing thorny bushes or small trees like, <i>Ziziphus jujube</i> (Ber). • Development of silvi-pastoral system on village grazing lands. • Utilizing village ponds for aqua forestry. • Development of comprehensive technology introduction plan. 	<ul style="list-style-type: none"> • Identification of research needs for implementation of technology design on target watershed. • Planning further D & D attention on non crucial areas, like village grazing land, incorporating other improved agro-technique for crop production (in addition to introduction of high yielding crop varieties as planned), etc. • Development of detailed project proposal for implementation of appropriate technological interventions to strengthen structure and production potential of existing tradition agroforestry system of the area to enhance livelihood security of villagers.

		<p>25% of total fodder need.</p> <p>Fuel: Only 35-50% fuel is produced from woody perennials on croplands; Heavy extra-territorial collection of fibre wood; thus, there is acute gap in demand and supply of fire wood.</p> <p>Economy: Serious indebtness prevails through out the villages of watershed. Cash assets and reserves are very meager.</p> <p>Production Constrains</p> <p>Crop lands: Low fertility; lack of adequate quantity of manure; low available moisture; soil erosion due to high wind speed; lack of knowledge and as well as availability of quality seeds.</p> <p>Grazing lands: Highly degraded; Extremely low production of forage and fuel wood.</p>		
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Entire interactive D & D process is shown in Fig.3.1.

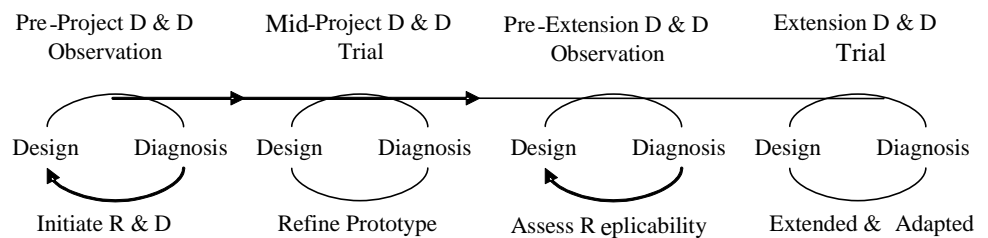


Fig.3.1: Entire interactive D & D process

Thus, D & D exercise is a continuous process, which is done time and again to develop and implement a perfectly designed agroforestry project in a target area.

3.2.5 You Can Do It

You can carry out a D & D exercise on your own up to technology design stage. Select a small village in your locality and visit it. During the first visit, interact with villagers and gather information about village population (human and livestock), land under agriculture, crops cultivated by villagers, trees growing on crop lands and farm bunds and at and around households, economy of farmers, fodder availability (from trees and crops), fuel wood sources, etc. After the first visit, arrange the information in a note sheet under the heading 'Pre-diagnostic Survey'. The help of Panchayati Raj Institutions can be sought for collection of relevant data pertaining to the selected village.

During the second visit to the village, collect information about crops grown and their productivity, fuel and fodder availability and requirement, source of drinking water, etc. including the problems faced by them in growing crops, collecting fuel wood and fodder and other problems relevant to their livestock rearing, etc. List the problems and select three problems (i) related to food crop production, (ii) related to fuel wood resources and availability and (iii) related to fodder resources and availability.

Select a farmer during the third visit and seek information pertaining to the problems being faced in crop production and fuel wood and fodder resources and availability. Make a rough sketch of the farm of selected farmer and show the tree species and their location, location of farm pond/tube well/ hand pump/ any other water source, if any, etc. Collect information regarding farm size, farmer's livestock wealth and family members. Based on data collected, develop an agroforestry land use project for optimum utilization of selected farm particularly for solving the identified problems.

Check Your Progress 1

Note: a) Compare your answers with those given at the end of unit.
b) Use the space below for your answers.

1) Indicate if the following statements are true or false by putting a tick mark (✓) in relevant box.

	True	False
(a) Agroforestry has two main objectives in broad sense <i>viz.</i> , productivity and sustainability.	<input type="checkbox"/>	<input type="checkbox"/>
(b) Diagnosis and development exercise is commonly referred to as D & D exercise.	<input type="checkbox"/>	<input type="checkbox"/>
(c) D & D exercise was developed as a programme of ICFRE (Indian Council of Forest Research & Education) in 1980s.	<input type="checkbox"/>	<input type="checkbox"/>
(d) D & D exercise consists of a series of information and analytical steps.	<input type="checkbox"/>	<input type="checkbox"/>
(e) D & D exercise starts with diagnostic stage.	<input type="checkbox"/>	<input type="checkbox"/>
(f) Diagnostic stage of D & D exercise involves diagnostic survey of selected systems.	<input type="checkbox"/>	<input type="checkbox"/>

2) (a) Write four stages of D & D exercise in sequence.

.....
.....
.....
.....

(b) Write three steps of technology design stage of D & D exercise.

.....
.....
.....
.....

3) Fill in the blank (s) with appropriate word (s).

- (a) D & D methodology is derived from analogy with medicine i.e., diagnosis should precede
- (b) In D & D exercise ‘Design’ means development of appropriate approach.
- (c) The D & D exercise consists ofstages involving twelve steps.
- (d) Identification of major land use problems and potentials is a step of stage of D & D exercise.
- (e) D & D exercise is carried out in mode up to maximum possible extent.

3.3 PARTICIPATORY RURAL APPRAISAL (PRA) FOR CHOICE OF SPECIES AND NEED

D & D exercise is conducted to identify agroforestry interventions required in a particular set of farming systems to enhance overall productivity and sustainability. It starts with diagnosis of the problem and potential of a particular farming system and ends up with agroforestry project planning and implementation involving a series of steps. Participatory Rural Appraisal (PRA) for selection of tree or woody species as per farmers’ needs has been used extensively in India to understand and assess rural situations and plan for their development since mid 1990s. Two main important aspects of PRA are:

- emphasis on participation of village people in their own development; and
- active and ongoing presence in a defined rural area not as a “patron” and “benefactor” but as a “catalyst” and “partner” in development.

PRA was developed primarily as an extension tool recognizing the weakness of extension or development workers/specialists to prepare particular village development plan as per their perception of needs of villages. In case of PRA, extension/development workers are still main actors; however they act more as

learners, conveners, catalysts and facilitators in order to ensure the wholehearted participation of rural people in investigation, analysis and presentation, planning and the outcome. The D & D exercise developed by the World Agroforestry Centre contains several elements of PRA. Identification of appropriate agroforestry tree species according to needs of villagers is the main focus of the PRA exercise. The following procedure is followed:

3.3.1 Transect Analysis

The following steps are used:

- find local people who are knowledgeable and willing to walk and help. Discuss with them primarily about tree species growing on or around crop fields, village common lands, around village ponds, streams, wells, etc. and also discuss about soils, crops, etc. After that assign task to them (who will do what?);
- transect walk and observe, ask and listen the members of the team (don't lecture); and
- discuss with the team members about the use of tree species growing here and there on transect route and also ask them what type of tree species they would like to plant. Finally make a transect diagram with the help of team members (Fig. 3.2).

The first hand information regarding tree species status in existing agroforestry system of the village and preliminary information regarding choice of tree species of villagers is thus obtained to fulfill their important needs.

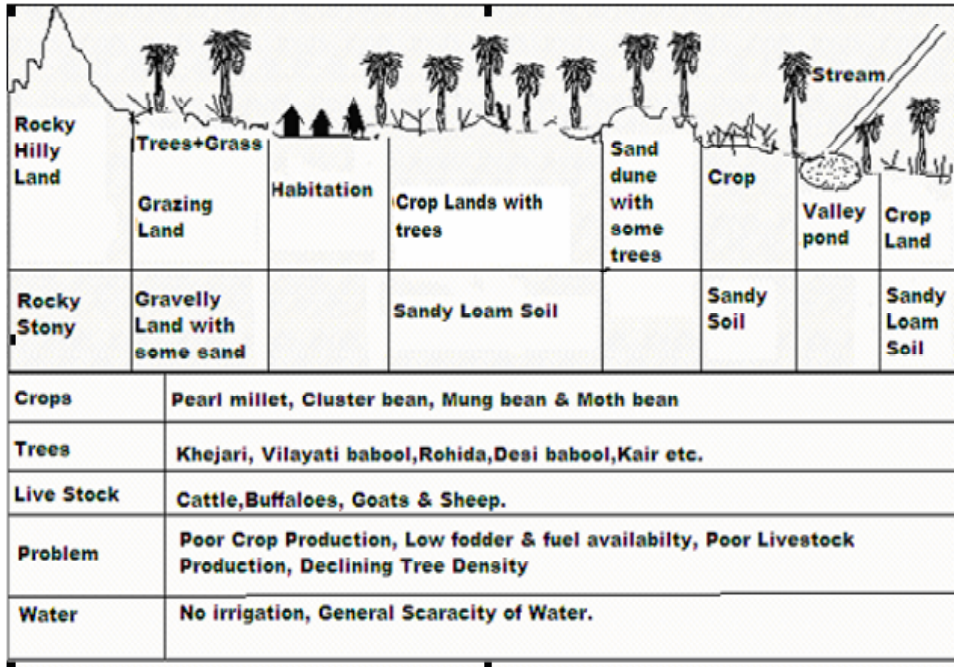


Fig.3.2: A geographical transect analysis of a village of arid Western Rajasthan

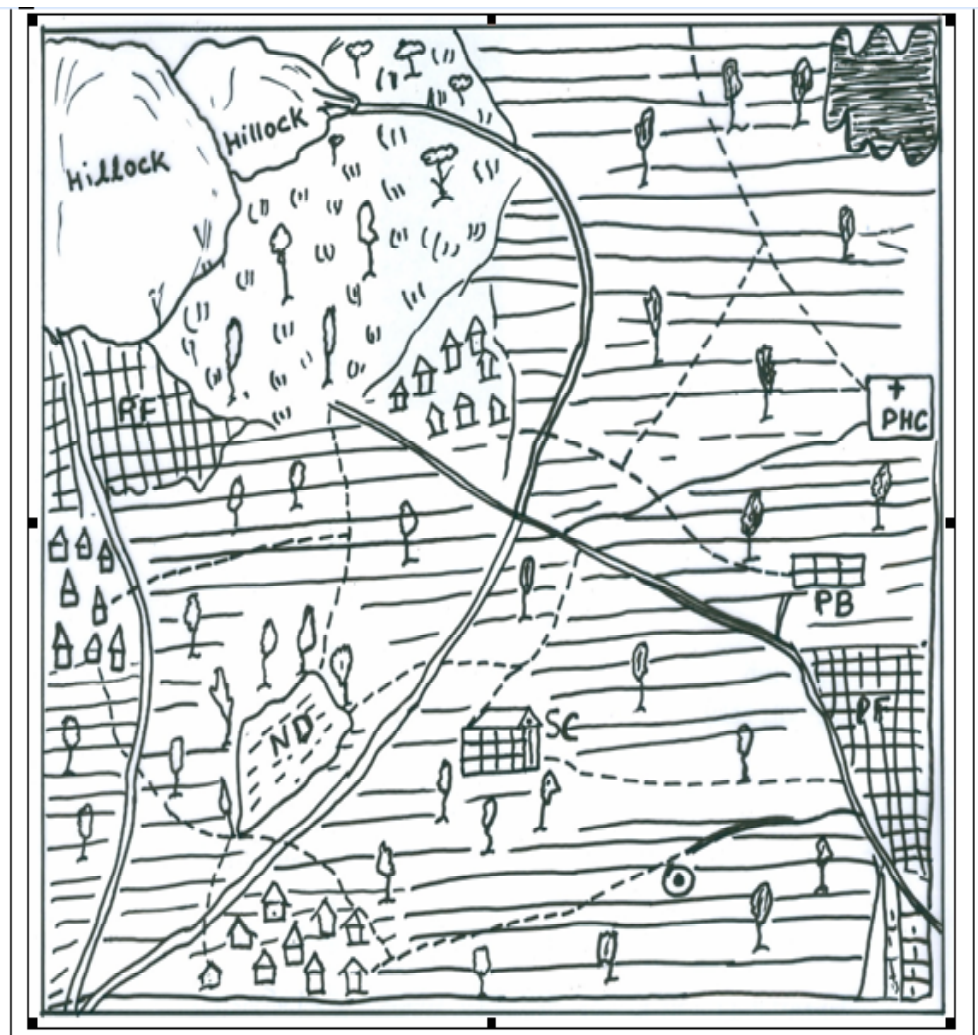
3.3.2 Mapping

In PRA, mapping of various aspects such as social mapping, soil mapping, primary resource mapping, watershed mapping, etc. is undertaken. Primary resource (land, water, crop, tree resources etc.) mapping of the village is required for selection

of tree species for agroforestry. Following procedure is adopted for the participatory primary resource mapping:

- constitute a team of villagers who know and are willing to share their knowledge;
- choose a suitable place and medium; for ground, sticks, stones and rangoli are required whereas pens, pencils, etc. for a plain large paper sheet;
- get team members to draw the natural resource map and assist them in marking various natural resources of the village on the map. Do not interfere or interrupt the team members while they are busy in drawing the map except occasionally when it is absolutely essential and encourage correction/additions during mapping; and
- if map is drawn on the ground, draw it on paper also exactly in the same manner with active participation of team members.

The resource map of the village provides all the relevant information such as type of agroforestry system and the fuel, fodder, timber, fruit, etc. tree species growing in the system. It also helps to assess the arrangement of tree species on the crop lands (e.g., scattered trees on crop lands, trees on farm boundaries, trees on village grazing lands, etc.). A participatory primary resource map is given in Fig. 3.3.







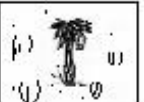

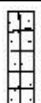



	Streams (Rainfed)	SC	Village School
	Pucca Roads	PB	Panchayat Bhawan
	Kachha Roads	+ PHC	Primary Health Center
	Permanent Fallows	ND	Nadi (Village Pond)
	Village Grazing Land (Trees +Grasses)		Crop land with trees
	Village Market		Tube well
	Sand dunes		Habitation

Fig.3.3: Natural resource mapping of a village of arid Western Rajasthan

3.3.3 Seasonality Diagram

Seasonality diagrams can be used for obtaining pattern of rainfall, employment, income and expenditure, debt, credit, food and nutrition, fuel wood production, tree leaf fodder production, milk production, etc. However, fuel wood and leaf fodder production and yield of other tree products are the important aspects for selection of tree species. Following procedure is used to prepare participatory seasonal diagram:

- identify the people who are willing to share their knowledge about women, men, children, landless, etc;
- interact with them regarding the problems for which you want to develop seasonality diagram is to be developed;
- mark units on the ground/floor using stones, chalk or any other suitable material;
- determine duration for important aspects such as rainfall, availability of tree leaf fodder, fuel wood, and other tree products and draw seasonality diagram by using stones, seed, fruits, lengths of sticks, chalk, etc. After preparing the diagram on the ground, draw exactly similar one on the paper.
- enquire discuss and encourage analysis of the participants and do not instruct the participant at any point of time. While developing seasonality diagram, do not impose your calendar.

A participatory seasonal diagram (Fig. 3.4) would provide precise information about fuel wood and fodder (tree leaf fodder), collection time and their availability, and also about other tree produce. This will ultimately help to determine the choice of agroforestry tree species as per needs of the end users i.e. the villagers.

Rainfall	–	–	–	–	–	.	...	...	..	–	–	–
Fuel Wood Availability Trend	..	..	.	.	.	–	–	–	.	..	....	...
Tree Leaf Fodder Availability Trend	..	.	.	–	–	–	–	–	.	..	....	...
Fuel Wood Requirement Trend	....	...	...	..	..	..	..	...	...	...	....	....
Tree Leaf Fodder Requirement Trend	....	....	...	...	...	..	.	.	.	..	...	....
Exuded Gum Availability	–	–	..	...	.	.	–	–	–	.	–	–
Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec

Fig.3.4: Seasonality diagram and tree leaf fodder availability and requirement in a village of arid western Rajasthan

3.3.4 Ranking and Scoring

Ranking or Matrix Ranking and scoring are most important PRA method for selection of agroforestry species. This can also be used for ranking items such as crops, varieties, types, trees for fodder, trees for fuel wood, trees for timber, trees for other products like, gum, fiber, etc. Following procedure is used for matrix ranking:

- decide the ranking of fuel wood trees, fodder trees, horticultural trees, etc. and discuss with well-informed villagers;
- discuss with team members about positive and negative points of a particular trees species;
- enumerate the criterion identified to rank or score each item. The score can be used as per your choice. If there are only few items, set the score out of 10, for a few more items set the score out of 5 and if there are many items, you can set the score out of 3. The highest score will indicate the most preferred; and
- undertake this exercise with people representing different social groups.

The villagers can identify most preferred agroforestry tree species by matrix ranking and accordingly the plantation programme of the preferred species on farmers’ fields, around farm boundaries, on village grazing lands, etc. may be planned. A ‘matrix ranking’ exercise conducted at Bambore- Baorli Watershed located at 39 km north-west of Jodhpur (Fig. 3.5) shows that ‘*khejeri*’ is most

preferred species for fodder and Angrezi babool for fuel wood followed by ‘Anjan’ and ‘Ber’. Selection of species by villagers themselves using above PRA methods leads to successful agroforestry programmes.

PARTICULAR	KHEJARI (<i>Prosopis Cineraria</i>)	ANGREZI BABOOL (<i>P.Juliflora</i>)	DESI BABOOL (<i>Acacia nilotica</i>)	ISRAELI BABOOL (<i>A.tortilis</i>)	ANJAN (<i>Hardwickia binata</i>)	BER (<i>Ziziphus Species</i>)
Not a good fuel wood tree
Not a good fodder tree	-	-	-
Pods are not good as fodder	-	-
Does not allow to grow crops	-	..	-
Not easy to collect fuel wood
Not easy to collect or use as fodder (Leaves/ Pods)
Tree leaves are not preferred by livestock	-	.	-
Will not prefer to grow on cropland	-	..	-

Fig.3.5: Matrix ranking (Score out of 5. Each circle represents one point in the score) of fuel wood and fodder tree species. Exercise conducted by villagers in Bambore – Baorli watershed (Arid – Western Rajasthan)

3.3.5 You Can Do It

Conduct the exercise in the selected village for selection of tree species for non agricultural livelihood by using above PRA methods. First, develop rapport with the villagers and select key informants for accomplishing task of transect analysis, primary resource mapping, seasonality diagram and matrix ranking. Inform the villagers about your correct date and time of your next visit. Prepare your report on the most preferred agroforestry tree species after analyzing data gathered with active participation of the villagers based on PRA methods.

Check Your Progress 2

Note: a) Compare your answers with those given at the end of unit.

b) Use the space below for your answers.

1) Fill up the blank(s) with appropriate words:

- a) Full form of PRA is
- b) PRA gives emphasis on of village people in their own development.
- c) In case of fuel wood tree species seasonality diagram gives information about time and of fuel wood from existing trees in village agroforestry system.
- d) Ranking and scoring is also referred to as

2) Indicate the following statements are true or false by putting tick (✓) in relevant box.

	True	False
(a) Transect analysis is a method of PRA.	<input type="checkbox"/>	<input type="checkbox"/>
(b) PRA mapping is done only as social mapping.	<input type="checkbox"/>	<input type="checkbox"/>
(c) In PRA exercise, village communities are involved to make their own development plan.	<input type="checkbox"/>	<input type="checkbox"/>
(d) Matrix ranking gives the idea about seasonal availability and demand of fuel wood and fodder.	<input type="checkbox"/>	<input type="checkbox"/>
(e) PRA exercise is conducted by calling villagers of selected village to research station.	<input type="checkbox"/>	<input type="checkbox"/>

3.4 SURVEY OF MULTIPURPOSE TREE SPECIES (MPTS) AND THEIR USES

The term “agroforestry species” usually refers to woody species also known as “multipurpose trees” (MPT). Multipurpose trees and shrubs are referred to as MPTS. MPTS in agroforestry include fuel wood species, fodder trees, fruit trees, etc. Besides, MPTS, herbaceous species are equally important in agroforestry. All trees are in fact multipurpose; however, some are more multipurpose than others in agroforestry context. Multipurpose trees are those trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or services in a multiple-output land use system. The terms fodder trees, fuel wood species, and sometimes fruit trees, represent important groups of MPTS (Nair 1993; Huxley 1999). On the basis of their use, MPTS. are briefly described as under:

3.4.1 Fodder Tress

A large number of topical trees and shrubs are traditionally known for their fodder use. Singh (1982) reported several such species from India and Nepal. A state of art account of “trub” (a collective name of trees and shrubs) species is given by Le Houérou (1980), who suggested that technologies based on permanent feed supply from fodder “trubs” could transform pastoral production systems into settled agro pastoral systems. In India, tree leaf fodder is extensively used in livestock husbandry.

In hot arid region of India especially in Western Rajasthan and parts of Gujrat and Haryana, leaves of *Prosopis cineraria* and various species of *Z. zizphus* are important source of fodder for livestock. In Indo-Gangetic plains of Central India, leaves of *Acacia catectu*, *Albizia amara*, *A. lebbek*, *A. procera*, *Morus alba*, *Sesbania grandiflora* and *Ziziphus* species are extensively used as livestock fodder. Pods of *Acacia nilotica* are also used as fodder in many parts of India. In different parts of the country, different woody species are used as sources of leaf fodder which are generally very nutritious.

3.4.2 Fuel Wood Trees

Like fodder tree species, a large number of tree/shrub species have been identified as fuel wood crops. In agroforestry, fuel wood or fire wood trees refer to woody perennials suitable for deliberate cultivation to provide fuel wood for cooking,

heating and lightening. Fuel wood even at present is the major source of fuel in villages of our country. Even in urban areas, fuel wood is used for cooking by large number of people. A large number of tree species are used as fuel wood species. U.S. National Academy of Sciences has identified 1200 species in the world as fuel wood species out of which 700 have been given top ranking based on their potential value or importance.

3.4.3 Fruit Trees

The traditional farming systems of many countries often include several fruit trees. These are common components in most home gardens and mixed agroforestry systems and are also integrated with arable crops in one form or other. In home gardens of Kerala state, coconut trees, cashew-nut trees, banana, etc. are generally found with rice crop and other economic taxa. Peach, guava, prunus and other fruit trees are found on terrace boundaries in western Himalaya (terraced land is used for arable crop farming). Fruit trees are one of the most promising groups of agroforestry species based on the biological and socio-economic attributes of fruit trees and their role in agroforestry systems (Nair 1993).

3.4.4 Other Woody Perennials

Agroforestry mainly constitutes about 50-60 tree and shrub species. However, in many developing countries, rural population derives a significant part of their food and other basic needs from various indigenous trees and shrubs that are seldom cultivated. Many of these species occur naturally in forest environments without making efforts for their domestication, improvement, or exploitation. A vast majority of such species, however, are quite restricted in their distribution and virtually unknown outside their usual range. For instance, Ban oak (*Quercus leucotrichophora*) in Uttarakhand and Himachal Pradesh Himalayan ranges provide excellent fuel and leaf fodder. Similarly, *Ziziphus rotundifolia*, shrub species in arid and semi-arid regions of India has tremendous potential to supply fuel wood, leaf fodder and fruits (for human consumption). However, their agroforestry value is never acknowledged. There are numerous such tree species which require scientific attention from agroforestry point of view. Table 3.2 shows relationship of various attributes of MPTs with their performance in agroforestry system.

Table 3.2: Relationship of Various Attributes of MPTs with Performance in Agroforestry Systems

Tree attributes	Performance in Agroforestry Systems
Height	Ease of harvesting leaf, fruit and branch wood.
Stem form	Suitability for timber, posts and poles, shading effect.
Crown architecture	Quantity of leaf and fruit production, shading, wind effect.
Multi-stemmed habit	Fuel wood and pole production.
Rooting pattern (deep or shallow, spreading)	Competitiveness with other components, particularly resource sharing with crops.
Physical and chemical composition of leaves	Fodder.
Thorniness	Suitability for barriers.
Response to pruning and cutting	Use in alley farming, lopping and copping.
Possibility of nitrogen fixation	For soil enrichment, planted fallows, rotational systems.

3.4.5 Procedure for Survey of Multipurpose Tree Species/ Shrub Species (MPTS)

Identify MPTS species by a rapid survey in a nearby village by including the following items:

- name and location of village;
- climate- temperature, rainfall, etc.;
- common tree species growing in the village;
- common shrub species found in the village; and
- trees/shrubs growing on crop fields or out-side crop fields.

Besides the above information, obtain the following information from villagers about each specie:

- (a) Main use of the species (fodder, fuel wood, timber, gum production, etc.).
- (b) Location where the species are found (crop fields or farm bunds or village grazing lands or on all the location of village).
- (c) If species are used for two or more purposes like, fuel wood, leaf fodder, minor timber, etc., rank (score) them according to priority of use (For example, *Acacia nilotica* in Indo-Gangetic Plains will have the priority as: Fuel < Timber < Fodder).
- (d) Develop a summary Table of MPTS and their uses.

Species	Common Name	Use (s)
<i>Acacia nilotica</i>	Babood	Fu (7); T (6); Fo (3)*
<i>Azadirachta indica</i>	Neem	M (8); Fu (5); T (5); Fo (4)
<i>Dalbergia sissoo</i>	Shisham	T (9); F (2)' Fo (1)
<i>Mangifera indica</i>	Aam	Fr (10); T (5)
<i>Prosopis cineraria</i>	Khejari	Fo (10); Fu (8); Fr (5)
<i>Prosopis juliflora</i>	Angrezi babool	Fu (10); Fo (4)*
<i>Tectona grandis</i>	Teak	T (10)
<i>Zizphus manuritiana</i>	Ber	Fr (8); Fo (8); Fu (3)

Fu = Fuel; T = Timber; Fo = Fodder (leaf); Fr = Fruit; M = Medicine

*Pods are used as fodder.

Scoring for each use is out of ten. Higher the score, more is the value of the species for particular use.

3.4.6 You Can Do It

The survey of MPTS is undertaken following the above procedure. Scoring indicates the most prominent and secondary use of the particular MPTS. For

scoring, own criterion can be devised. However, the criterion should provide the clear insight into various uses of MPTS.

Check Your Progress 3

Note: a) Compare your answers with those given at the end of unit.

b) Use the space below for your answers.

1) Fill in the blank (s) with appropriate words.

- (a) Multipurpose trees and shrubs are commonly represented as
- (b) Collective name for tree and shrub is
- (c) US National Academy of Sciences has identified tree species as fuel wood species over the world.
- (d) forms the chief source of fire energy in villages of India.
- (e) Tree and shrub species having thorns are suitable for
- (f) Home gardens have species as most common component.

3.5 INDIGENOUS AGROFORESTRY SYSTEMS, INDIGENOUS KNOWLEDGE, SHELTERBELTS AND AQUAFORESTRY

This section deals with some examples of indigenous or traditional agroforestry systems and about traditional knowledge of farmers in context of managing such systems. In Thar desert of arid western Rajasthan, an age old tradition of growing pearl millet (Bajra) under the canopies of *Prosopis cineraria* trees commonly known as 'khejari' is practiced. The density of khejari trees on farmers' fields varies from 5-8 to high as 40-50 trees/ha. Khejari trees support good growth of pearl millet and a large number of grass species (Narain and Tewari 2005). *Zizphus nummularia* (Thar Ber), *Azadirachta indica* (Neem), *Salavdora* spp. (Jal) and *Acacia* species (Babul) are other beneficial multipurpose trees and shrubs used in arid western Rajasthan.

In fact, in fragile ecosystems of arid western Rajasthan, agriculture alone cannot be a dependable enterprise, hence desert dwellers with their traditional wisdom are integrating trees into crop fields since time immemorial to ensure stability and generate assured income. As most of the trees are drought resistance, they provide fuel, fodder and other products, when arable crops fail due to recurring droughts or low rainfall in the region.

In central Himalayan region, Uttarakhand, indigenous agroforestry has been practiced for a very long time. However, the structure of this traditional agroforestry system is more than simple combination of woody and herbaceum components on same unit of land. It includes interaction among three components: (i) crop fields, (ii) trees (fuel, fodder and fruit trees) in and around crop fields and (iii)

natural forests and community forests around the village. Some of the common tree species grown by villages on crop lands are *Grewia optiva*, *Quercu leucotrichophora*, *Bacilinia varigata*, *Ficus roxiburghii*, *Bohmeria regulose* and *Toone ciliata* (fuel, leaf fodder and timber yielding species), and *Prunus persisa*, *Pyrus communis*, *Citrus lemon*, *Pnums malus*, *Psidium guagava*, etc. (fruit species). Natural and community forests play a significant role in functioning of this kind of agroforestry systems.

In Indo-Gangetic Plain, farmers practice agroforestry in many forms. In indigenous agroforestry systems of this vast tract, *Acacia nilotica* (Babul), *A. catcchu* (khair), *Albiziz amara* (kala siris), *Albizia lebbek* (Desi siris), *Azadirachta indica* (Neem), *Bombax cieba* (Semal), *Embllica officinalis* (Amla), *Moringa oleifera* (Sahjan), *Syzygium cumini* (Jamun), *Ziziphus mauritiana* (Ber), etc. growing on and around the crop lands are found. However, density of trees in this region is very low as compared to arid western Rajasthan and Uttarakhand. These trees are mainly used for fodder and minor timber purposes.

A unique type of indigenous agroforestry system known as 'home garden' is found in Kerala. In fact, home gardens have a long tradition in many tropical countries. These gardens are planted and maintained by members of the households and their products are used primarily for their consumption. Though home gardens are very small in size but species diversity is very high. Plantation crops like coconut, *Areca catclu* etc. form the top layer of canopy whereas, trees of banana, guava, yam papaya, etc. are generally grown in the second layer with the lower most layer dominated by different vegetables and medicinal plants. Rice and other crops are taken as ground layer crops. Poultry, fish, sheep and cattle farming is also practiced in home gardens (i.e., in same unit of land). Thus, it is a very complex indigenous agroforestry system providing large number of products. Shifting cultivation practiced in north-eastern region of India, and Tungiya cultivation (discussed in Unit 1) in north-eastern region, foot hills of Uttarakhand and Tarai region of U.P. and Bihar are also indigenous agroforestry systems. Evolution of such traditional or indigenous agroforestry systems in the country is governed by edaphoclimatic and socio-economic situation of particular region.

These systems are managed by the traditional knowledge which is quite refined as it has been in practice for a very long time. The farming communities are familiar with the art of managing such systems for higher production in time and space.

There are two unique agroforestry practices, shelterbelts of arid western Rajasthan and aqua forestry. Planting multipurpose trees around the crop fields is an age old practice in arid Western Rajasthan. As average wind speed is very high during summer season (20-30 km/hour with high of 80-100 km/hour) resulting in dust storms and consequent severe wind erosion. The trees on farm bunds provide some degree of protection to crop lands from soil erosion due to high wind speed. Shelterbelts are simply the rows of trees planted against the wind direction. Commonly three rows of trees are planted in a staggered manner so that some wind can pass through the shelterbelt also, which is essential to provide wind stability to trees. In three rows shelterbelt, middle row consists of fast growing tall

trees like *Acacia tortilis*, *Azadirachta indica*, *Albizia* species and in outer rows short stature trees or shrub species are grown so that a fully developed shelterbelt has pyramidal architecture. Such pyramidal shape of shelterbelt is the most effective against wind erosion. The most common species used in side rows are *Prosopis juliflora*, *P. chilensis*, *P. alba*, *Capparis deciduas*, *Perkinsonia aculata*, etc. Three rows shelterbelt helps in checking wind erosion up to a distance of $20H$ (H = height of shelterbelt) which means that if the height of trees of central row of shelterbelt is 15 m, the soil erosion can be controlled up to a distance of $15 \times 20 = 300$ m. Such a shelterbelt has been successfully used along canal banks Indira Gandhi Nahar Pariyogana (IGNP) in western Rajasthan.

Aquaforestry is also a kind of agroforestry practice wherein trees are grown all around the fish ponds. The tree leaves not only provide feed for fish but also improve microclimate to help in boosting fish production.

Check Your Progress 4

Note: a) Compare your answers with those given at the end of unit.

b) Use the space below for your answers.

1) Indicate true or false by putting tick (✓) in relevant box.

	True	False
(a) Traditional agroforestry system practiced by the farmers is also known as indigenous agroforestry system.	<input type="checkbox"/>	<input type="checkbox"/>
(b) In arid western Rajasthan, <i>Syzygium cumini</i> is the most common tree species of traditional agroforestry system.	<input type="checkbox"/>	<input type="checkbox"/>
(c) Forests in and around villages also forms a component of traditional agroforestry system of Uttarakhand Himalayan region.	<input type="checkbox"/>	<input type="checkbox"/>
(d) Home gardens are commonly found in Punjab state.	<input type="checkbox"/>	<input type="checkbox"/>
(e) Shelterbelts help in reducing the intensity of wind erosion.	<input type="checkbox"/>	<input type="checkbox"/>
(f) Growing trees for fish forage around fish ponds is known as aqua forestry.	<input type="checkbox"/>	<input type="checkbox"/>
(g) Coconut is a forest tree crop.	<input type="checkbox"/>	<input type="checkbox"/>
(h) Shifting cultivation is a kind of indigenous or traditional agroforestry system.	<input type="checkbox"/>	<input type="checkbox"/>

3.6 CONCEPT OF NATURAL RESOURCE SURVEY AND ECONOMICS

3.6.1 Concept of Natural Resource Survey

Natural resource survey approach is considered for natural resource planning, management and development. The natural resource survey includes collection of

information and developing a data base on landforms, soils, surface and groundwater, present land use, vegetation, etc. In context of agroforestry, natural resource surveys involve collection of information on extent of distribution, structure and production function of agroforestry systems of different agro-ecological/agro-climatic zones or particular area. Natural resource survey is a prerequisite for natural resource management aiming at efficient and sustainable utilization of renewable and non-renewable natural resources. In context of agroforestry, natural resource survey refers to inventory of biophysical resources which are essential for production of food, feed, fiber, fuel, minor timber, other products of economic importance like gums, fruits, etc. Natural resource of interest includes all those affected by production process (e.g., soil, water, biodiversity, fish, livestock and forest).

Diverse ecosystem services generated through ecosystems' functions, therefore, provide various economic, environmental and socio-cultural benefits and values to people. deGroot et. al. (2002) developed a typology for the classification of ecosystem functions and services. Although this typology is meant for natural ecosystems, it can be adapted to use in agroforestry system survey to understand the functioning of natural resources involved in evolution of particular kind of system. Such a natural resource survey includes following functions of a particular agroforestry system:

- production;
- regulatory services;
- habitat; and
- socio-cultural (information) service.

Production of food and raw material is a major function of any agroforestry system that includes food, feed, fuel, raw materials, medicines, etc. The regulatory services relate to role of agroforestry systems in maintenance of essential ecological processes and life support systems. Such regulatory services influence and regulate climate change (e.g. through carbon sequestration), water flows (runoff and river discharges) and protect soils from erosion, water supply through filtering, retention and storage of fresh water (e.g. check dams, anicuts, etc.); soil formation through decomposition of organic matter; nutrient regulation through storage and recycling of nutrients, etc. The habitat functions indicate the useful services provided by agroforestry systems in terms of habitats. It is difficult to develop indicators for survey of this function. However, the habitat function as number of species in given habitat, micro-climate improvement of habitat by woody component of agroforestry system, etc. has to be clearly understood. Agroforestry systems provide socio-cultural services like aesthetic information (attractive landscape), recreational activity (e.g. agro-tourism), etc. to the community as a whole.

A general approach to natural resource survey involves stage by stage information collection, assessment and interpretation. The following successive steps would be logical ideal sequence for such survey.

- Regional reconnaissance survey includes (a) segmentation of region into areas with distinctive natural resource characteristics, (b) preliminary technical interpretation of these resource factors and (c) selection of those areas with most promising combination of resource factors.
- Post-reconnaissance activities include (a) more detailed survey in promising areas selected by reconnaissance survey, (b) assessment of

social and economic feasibility for a particular R & D programme (in present case type of agroforestry practices needed and (c) more detailed examination for precise planning of the implementation of a particular R & D project.

3.6.2 Economic Consideration

Economic considerations are most important to determine the feasibility of agroforestry to the land user. Agroforestry analysis for long term characterization should address five major points:

- (a) Does the system under evaluation make the best use of available resources?
- (b) In event of commencement, would available financial resources of land user permit completion of all the activities?
- (c) Is system technically feasible under prevalent labour constraint?
- (d) Is the system economically viable under given capital constraint of land user?
- (e) What are the risks involved in establishment of a particular agroforestry system?

Detailed economic analysis of agroforestry systems/practices is a complicated issue; however, simple benefit-cost calculation is enough for its understanding. Following example of economics of traditional agroforestry system of western Rajasthan by Narain and Tewari (2005) illustrates economics of agroforestry systems.

Arid Western Rajasthan supports a variety of traditional or indigenous agroforestry systems. As already explained, the overall environmental conditions of the region are quite unfavourable for arable crop production with recurring droughts. Therefore, farmers practice tree and crop combinations in the region since time immemorial, as trees provide at least fuel, fodder and some minor tree produce like gums, etc. even incase of complete crop failures. Table 3.3 illustrates simple economics of traditional agroforestry systems of arid Western Rajasthan.

Table 3.3: Economics of Traditional Agroforestry Systems

AF Systems	Expenditure (Rs/ha)	Returns (Rs/ha)			Gross Returns (Rs/ha)	Gross B:C Ratio	Net Return (Rs/ha)	Net B:C ratio
		Crop	Fuel wood	Leaf fodder				
<i>Prosopis cineraria</i> – <i>Acacia nilotica</i> based	1850	4103	1230	870	6203	3.4	4353	2.3
<i>Prosopis cineraria</i> based	1550	3670	600	420	4690	3.0	3140	2.0
<i>Ziziphus</i> spp. based	1550	1506	620	600	2726	1.8	1176	0.7
<i>Z. spp.</i> – <i>P. cineraria-Salvadora</i> spp. based	1500	1400	500	500	2400	1.6	900	0.6

In fact, viability of agroforestry depends on the actual impact that it has on farmers economic and physical well being. From the above example, you can

analyze how tree produce substantially adds to farmers’ income from traditional crops. Moreover, potential environmental benefits of agroforestry are immense and their economic analysis require complex environmental impact assessment methodologies which is beyond the scope of this unit.

Check Your Progress 5

Note: a) Compare your answers with those given at the end of unit.
 b) Use the space below for your answers.

1) Indicate the following statements are true or false by putting tick (✓) in relevant box.

	True	False
(a) Natural resource survey is not carried out for natural resource planning.	<input type="checkbox"/>	<input type="checkbox"/>
(b) Natural resource survey is pre-requisite for natural resource management.	<input type="checkbox"/>	<input type="checkbox"/>
(c) Production of food and raw material is a major function of any agroforestry system.	<input type="checkbox"/>	<input type="checkbox"/>
(d) For land user, economic consideration is not important while developing any kind of agroforestry system.	<input type="checkbox"/>	<input type="checkbox"/>
(e) Economic analysis of agroforestry includes risks involved in establishment of a particular agroforestry system.	<input type="checkbox"/>	<input type="checkbox"/>

- 2) Fill in the blanks with appropriate word(s).
- a) Vegetation, soils and surface and groundwater are parts of
 - b) Natural resource survey in context of agroforestry system survey includes, and socio-cultural (information) services.
 - c) Economic analysis of agroforestry system give major importance to economic under given capital constraint of land users.
 - d) To understand the suitability of any agroforestry simple : ratio gives much needed information at first instance.

3.7 LET US SUM UP

- Survey and documentation of existing agroforestry practices involves number of components and each component has its own importance.
- Diagnosis and Design (D & D) exercise developed by World Centre for Agroforestry (formerly ICRAF), Nairobi, Kenya is an effective tool to survey and document the existing agroforestry practices/systems and design new projects or R & D programmes accordingly for the benefit of land users.
- D & D exercise is divided into four stages namely, prediagnostic stage, diagnostic stage and technology design stage consisting of twelve steps.

- Participatory rural appraisal (PRA) for choice of species for any agroforestry system/practice provides an opportunity to the farmers to opt for the trees, shrub and crop/grass species of their choice according to needs of edaphoclimatic and socio-economic condition of the region/area.
- Transect analysis, mapping, seasonality diagram and ranking and scoring are four most important components of PRA used for selection of agroforestry species. In PRA, the species are selected by the farmers themselves according to their needs and such species perform better due to the application of best available inputs and much needed protection. Seasonality diagrams and ranking and scoring methods further refine the procedure for selection of agroforestry species by the farmers.
- Multipurpose tree species (MPTs) or multipurpose trees and shrubs (MPTS) are those trees and shrubs which are deliberately kept and managed for more than one preferred use, product, and/or services in a multiple-output land use system. The terms fodder trees, fuel wood species and sometimes fruit trees, represent important groups of MPTs.
- Indigenous agroforestry systems in different parts of the country are of immense importance for different fodder, minor timber and other useful purposes. Evolution of such traditional or indigenous agroforestry systems in the country is governed by edaphoclimatic and socio-economic situation of particular region.
- Shelterbelts and aquaforestry are very useful agroforestry practices. Shelterbelts on farm bunds provide some degree of protection to crop lands from soil erosion due to high wind speed. Aquaforestry refers to trees grown all around the fish ponds which not only provide feed for fish but also improve microclimate to help in boosting fish production.
- Natural resource survey for natural resource management refers to inventory of biophysical resources such as soil, water, biodiversity, fish, livestock and forest which are essential for production of food, feed, fiber, fuel, minor timber, other products of economic importance like gums, fruits, etc.

3.8 KEYWORDS

Diagnosis and Design Exercise	: A survey methodology developed by World Centre of Agroforestry to identify problems followed by design and implementation of an agroforestry project.
Edaphoclimatic Conditions	: Related to soil and climatic conditions.
Indigenous Agroforestry System	: Traditional system of agroforestry practiced in an area or region conventionally since ages.
Indigenous Traditional Knowledge	: The traditional knowledge through which farmers manage tree and crop components of agroforestry system. Such knowledge is discussed from one generation to next.
MPTS	: Multipurpose Tree Species.

MPTS	: Multipurpose Trees and Shrubs
Natural Resource	: Soil, Water, Vegetation, Landforms, etc.
PRA	Participatory Rural Appraisal which refers to a kind of village resource appraisal undertaken by the farmers of the village without any interference of others.
Survey	: Surveying an area for defined objectives.

3.9 SUGGESTED READING

deGroot S.R., Wilson M.A. and Boumans R.M.J. (2002). A typology for classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* 41: 393-408.

Huxley Peter A. (ed.) (1983). *Plant Research and Agroforestry*. International Council for Research in Agroforestry, Nairobi, Kenya, 617 p.

Huxley Peter A. (1999). *Tropical Agroforestry*. Blackwell Science Ltd. Osney Mead., Oxford OX2 OEL, U.K.

Le Houerou H.N. (ed.) (1980). *Browse in Africa: The Current State of Knowledge*. ILCA, Addis Ababa, Ethiopia.

Nair Ramchandran P.K. (1993). *An Introduction to Agroforestry*. Kluwer Academic Publishers. Dordrecht, The Netherlands, 499 p.

Nairain P. and Tewari J.C. (2005). Trees on agricultural fields: a unique basis of life support in Thar desert. In: *Multipurpose Trees in the Tropics: Management & Improvement Strategy*. (eds.) V.P. Tewari and R.L. Srivastav, Arid Forest Research Institute (ICFRE), Jodhpur pp. 516-523.

Raintree J.B. (1987). D & D User's Manual: *An Introduction to Agroforestry Diagnosis and Design*, ICRAF, Nairobi, Kenya.

Singh R.V. (1982). *Fodder Trees of India*. Oxford and IBH Publishing Co., New Delhi.

3.10 MODEL ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

- 1) (a) True; (b) False; (c) False; (d) True; (e) True; (f) True
- 2) (a) (i) Predignostic stage; (ii) Diagnostic stage; (iii) Technology design stage; (iv) Follow- up planning stage
 - (b) (i) selection of candidate technologies for inclusion in design; (ii) synthesis of general design concept for an improved land use system and (iii) evaluation and refinement of proposed design.
- 3) (a) treatment; (b) agroforestry; (c) four; (d) diagnostic ; (e) participatory.

Check Your Progress 2

- 1) (a) Participatory Rural Appraisal; (b) participation of village people for their own development (c) collection time and availability; (d) matrix ranking.
- 2) (a) True; (b) False; (c) True; (d) True; (e) False

Check Your Progress 3

- 1) (a) MPTS; (b) Trub; (c) 1200; (d) Fuel wood; (e) barriers; (f) Fruit trees.

Check Your Progress 4

- 1) (a) True; (b) False; (c) True; (d) False; (e) True; (f) True; (g) False; (h) True

Check Your Progress 5

- 1) (a) False; (b) True; (c) True; (d) False; (e) True
- 2) (a) Natural resources; (b) Production, regulatory services, habitat;
(c) Feasibility or viability; (d) Benefit- Cost.