INTRODUCTORY AGROFORESTRY

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1. Introductory Agroforestry (HPA 100) 2 (1+1)\

2.

Agroforestry – definition, objectives and potential. Distinction between agroforestry and social forestry. Status of Indian forests and role in India farming systems. Agroforestry system, sub-system and practice: agri-silviculture, silvipastoral, horti-silviculture, horti-silvipastoral, shifting cultivation, taungya, home gardens, alley cropping, intercropping, wind breaks, shelterbelts and energy plantations. Planning for agroforestry – constraints, diagnosis and design methodology, selection of tree crop species for agro-forestry. Agroforestry projects – national, overseas, MPTS – their management practices, economics of cultivation nursery and planting (Acacia catechu, Dalbergia sissoo,, Tectona, Populus, Morus, Grewia, Eucalyptus, Quercus spp. and bamboo, tamarind, neem etc.)

Practical: Identification and seeds and seedlings of multipurpose tree species. Nursery practices for poplar, Grewia optiva, Morus alba, Acacia catechu, Dalbergia sissoo, robinia, leucaena etc. Visit to agro-forestry fields to study the compatibility of MPTS with agricultural crops: silvipastoral, alley cropping, horti-silviculture, agro-silvipasture, fuel and fodder blocks. Visit to social forestry plantations – railway line plantations, canal plantations, roadside plantations, industrial plantations and shelterbelts. Rapid assessment of farmers needs for green manure, fodder, fuel wood in selected villages. Economics and marketing of products raised in agro-forestry systems.

LECTURE-1

LEARNING OBJECTIVE: TO KNOW ABOUT AGROFORESTRY DEFINITIONS, OBJECTIVES, POTENTIAL AND DISTINCTION BETWEEN AGROFORESTRY AND SOCIAL FORESTRY

CONCEPT OF AGROFORESTRY

Agroforestry is an age old practice, indeed very old. Farmers of the tropical area have long tradition of growing food crops, tress and animals together as well as exploiting a multiple range of production from natural wood lots. Trees and forests are an integral part of the Indian culture. The best of Indian culture was born in the forests. Our rishis who evolved the Hindu philosophy, lived in forests in complete harmony with the nature. In fact, so much has been said about trees in our ancient literature that planting tree was being done by individuals on their own along with agriculture crops. "Krishishukti" written by Maharishi Kashyap, classifies land into several categories and identifies areas which are sustainable for planting trees, all wet and dry lands and areas around houses, wells, tanks are specifically identified for tree planting. But foresters and agriculturists, who have traditionally operated within rather rigid disciplinary boundaries concentrating on monoculture production of their preferred commodities of crops, animals and trees used to ignore such combined integrated production systems.

More recently, however, the forest area has receded and resources have shrunk considerably. The people are no longer able to meet their requirements of firewood, fodder, timber, bamboo, etc. from the forest. Due to shortage of wood the prices of these commodities have, therefore, increased substantially. Many forest based industries have been facing problems in supply of raw material. Many farmers quite recently started planting trees on their farm lands to meet these shortages along with agriculture crop; thus from the concept of agroforestry it emerged out

- Agroforestry is collective name for land use systems involving trees combined with crops and/or animals on the same unit of land. Further it,
- Combines production of multiple outputs with protection of resource base
- Places emphasis on the use of multiple indigenous trees and shrubs

- Is particularly suitable for low-input conditions and fragile environments
- Involves the interplay of sociocultural values more than in most other land-use systems
- Is structurally and functionally more complex than monoculture

AGROFORESTRY DEFINITIONS: -

- Agroforestry means practice of agriculture and forest/ horticulture tree on the same piece of land. However, the agroforestry has been defined by various workers working in the field of agroforestry. Some of the definitions given by different workers are as follows:
- Bene *et al. (*1977) defined agroforestry as a sustainable management system for land that increases overall production, combines agriculture crops, forest plants and tree crop and/or animals simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of a local population.
- King and Chandler (1978): "Agroforestry is a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially, on the same unit of land and applies management practices that are compatible with the cultural practices of the local population.
- Nair (1979) defines agroforestry as a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers.
- According to Lundgren and Raintree (1982), agroforestry is a collective name for land use systems and technologies, where woody perennials (trees, shrubs, palm bamboos, etc.) are deliberately used in the same piece of land management units as agriculture crops and/or animals in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economical interactions between the different components.

Some of the basic ideas emerging from the definition of AGROFORESTRY

- AF normally involves two or more species of plants (or plants and animals), at least one of which is woody
- An *AFS always has two or more outputs
- Cycle of the AFS is always more than one year
- Positive and negative interactions are exhibited among components (tree, crop)
- Even the simplest AFS is more complex ecologically (structurally and functionally) and economically, than a monocropping system

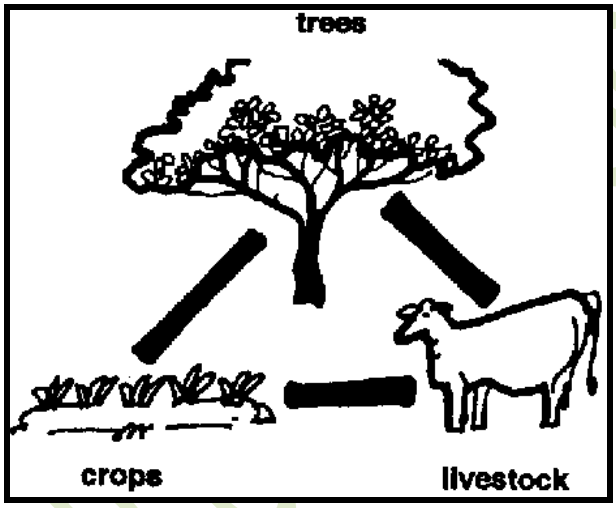

Plate1.1 Agroforestry components/Basic components of agroforestry

OBJECTIVES OF AGROFORESTRY

In all agroforestry land management there are two essential and related aims such as

- ✓ **The AFS should conserve and improve the site**
- ✓ **Optimize the combine production of tress, agricultural crops and animals**

ATTRIBUTES OF AGROFORESTRY

There are three attributes which, theoretically, all agroforestry system possess, these are:

- ✓ **Productivity**

Most, if not all, agroforestry systems aim to maintain or increase production (of preferred commodities as well as productivity (of the land). Agroforestry can improve productivity

in many different ways. These include: increased output of tree products, improved yields of associated crops, reduction of cropping system inputs, and increased labour efficiency.

- ✓ **Sustainability**

  By conserving the production potential of the resource base, mainly through the beneficial effects of woody perennials on soils, agroforestry can achieve and indefinitely maintain conservation and fertility goals

- ✓ **Adoptability**

  The word "adopt" here means "accept" and it may be distinguished from another commonly used word adapt, which implies "modify" or "change." The fact that agroforestry is a relatively new word for an old set of practices means that, in some cases, agroforestry already been accepted by the farming community. However, the implication here is that improved or new agroforestry technologies that are introduced into new areas should also conform to local farming practices

POTENTIAL OF AGROFORESTRY:

The different aspects in which agroforestry can help in enhancing the productivity of our lands to meet the demand of ever- growing human and livestock population. are as follows:

Meeting the demand of food & fodder

- Enhanced food production from crops associated with trees through nitrogen fixation, better access to soil nutrients brought to surface from deep tree roots, improved availability of nutrients due to high cation-exchange capacity of the soil and its organic matter and mycorrhizal associations
- Food for man from trees as fruits, nuts and cereal substitutes
- Fodder for meeting rural needs

Water conservation

- Improvement of soil-moisture retention in rainfed croplands and pastures through improved soil structure and micro-climate effect of trees
- Regulation of stream flow, reducing flood hazards and a more even supply of water through reduction of run-off and improvement of interception and storage in infiltration

galleries.

- Improvement in drainage from waterlogged or saline soils by trees with high water requirements.

Fuelwood and energy

- Fuel-wood for direct combustion
- Pyrolytic conversion products such as charcoal. oil and gas
- Ethanol produced from fermentation of high-carbohydrate fruits
- Oils, latex and other combustible saps and resins

Shelter from trees

- Building materials for shelter construction
- Shade trees for people, livestock and shade-loving crops
- Wind-breaks and shelter-belts for protection of settlements, crop lands, pastures and roadways
- Fencing: live fences and fence posts

Raw material for industries

- Raw material for pulp and paper industry
- Tannins. essential oils and medicinal ingredients
- Wood for agricultural implements and various crafts
- Fibre for weaving

Cash benefits

- Direct cash benefits from sale of tree products
- Indirect cash benefits from increased productivity

Increased yield and maximized production:

Combining agriculture crops with trees helps in increasing the productivity of the land by:

- Utilizing available solar radiations throughout the year and thus enhancing total productivity
- Many leguminous tree species fix nitrogen from the atmosphere and return much more in leaf fall than they take from soil.

- Leaves of tree species could be used as green manure and help the farmer to increase soil productivity at optimum levels over a long period of time.

Diversified products:

- Several trees, shrubs, herbs and climbers yield a substantial quantity of food materials which are used by rural poor and particularly by tribal.
- About 213 species of large and small trees, 17 species of palm, 128 species of shrubs, 116 species of herbs, 4 species of fern and 15 species of fungi are known to yield edible/food material.
- Thus, by adopting agroforestry one can get diversified products viz. fuel, fodder, fruits, fibre, timber, etc.
- Agroforestry aims to maximize production of biomass of trees and agricultural crops.
- Tree and agriculture crop production system is more productive and is capable of meeting almost all the demands of timber, fodder, fruits, fiber and firewood.

Utilization of wasteland and degraded land:

- In India approx 100 million ha area is under different kinds of waste land.
- These lands can be gainfully utilized for the cultivation of trees.
- Once the area is vegetated, ecological restoration process starts by means of leaf litter decomposition etc., which leads to improvement in soil condition.
- Once the soil is improved, this land can be utilized for agricultural production.

Provides employment opportunities:

- Unemployment is the country's main problem.
- Agroforestry systems increase the employment opportunities.
- Plantation, including seed collection and nursery raising generate employment of about 200-500 man days/yr.
- Wood based industries such as saw milling, furniture, sports goods, pulp and paper, Match splints, bamboo and cane furniture, etc. are the important sectors where rural youth get employment.

Increased farm income:

Agroforestry provides the farmers with large number of alternatives of agricultural, forestry and horticultural crops and thus gives more income to the farmers per unit of land than monoculture.

Carbon sequestration services and its influence on climate change.

One of the most important contributions of agroforestry in general is to respond to climate change through sequestration of carbon in above ground plant biomass and below ground biomass in the soils.

Potential reduction in the rate of deforestation

- Agroforestry reduced the annual rate of deforestation to a great extent.
- The ready availability of fuel wood in own farm reduces the burden on the natural forests.
- The time that household/family members especially women would have spent walking long distances in search of fuelwood in forests can be saved.

Improvement in soil health and insurance against climatic hazards

- Trees and shrubs improve the physical properties of soils.
- In particular aggregation is higher in fields where trees are being grown, and this enhances water infiltration and water holding capacity of soils thereby reducing surface run-off and soil erosion.
- As a result, trees /shrubs have the potential to reduce the impact of droughts, a common seasonal phenomenon in most of the developing countries where agriculture is mainly rain-fed.
- The repeated application of tree biomass increases the soil organic matter that leads to important increase in soil water retention capacity.
- The trees biomass also provide favourable environment for soil microbes and fauna which in turn break down the biomass and release plant nutrients.

Agroforestry as a habitat for wild species

- Agroforestry can enhance connectivity and landscape heterogeneity in multi-functional conservation landscape.

- Zomer *et al*., (2001) found that an agroforestry system viz *Alnus nepalensis* and cardamom contributed to the integrity of riparian corridors for wildlife conservation around the Makalu Barun National Park and Conservation Area of eastern Nepal.

SOCIAL FORESTRY:

- **S**ocial forestry is the practice of forestry on lands outside the conventional forest area for the benefit of the rural and urban communities.
- The term was coined by J.C. Westoby. It was first recognized as an important component of forestry for meeting rural needs in the interim report of the National Commission on Agriculture (NCA), 1976.
- The objectives of social forestry adopted by the NCA were to fulfill the basic and economic needs of the community.
- The scope of social forestry defined by the NCA included farm forestry, community woodlots and reforestation in degraded lands. By mid-1980, the concept of social forestry was firmly established as forestry 'for the people, with the people and by the people' or forestry of the people, by the people and for the people.

Social forestry includes within its scope the following:

a) Farm Forestry: Farm forestry is the practice of forestry on farms in the form of raising rows of tree on bunds or boundaries of field and individual trees in private agriculture land as well as creation of wind breaks, which are protective vegetal screens created round a farm or an orchard by raising one or two lines of trees fairly close with shrubs in between.

b) Extension Forestry—Extension forestry is the practice of forestry in areas devoid of tree growth and other vegetation and situated in places away from the conventional forest areas with the object of increasing the area under tree growth. It includes within its scope the following:

i. **Mixed forestry:** Mixed forestry is practice of forestry for raising fodder grass with scattered fodder trees, fruit trees and fuel-wood trees on suitable waste lands, panchayat land and village commons land.

ii. **Shelterbelts:** Shelterbelts is defined as 'a belt of trees and/or shrubs maintained for the purpose of shelter from wind, sun, snow-drift, etc. they are generally more extensive than the wind-breaks covering areas larger than a single farm and sometimes whole regions on a planned pattern.' **Or**

Shelterbelt is wide belt of tree, shrubs and grasses which goes right across the land at right angle to the direction of prevailing wind in order to

- Reduce wind velocity
- Deflect wind current
- Protect public properly in leeward side

iii. **Linear Strip Plantation:** These are plantations of fast-growing species on linear strips of land on the sides of public roads, canals and railway lines.

c) Community Woodlots: The community woodlots, consists of plantations of fuelwood species on community village lands, with intended objective of increasing a villager's access to fuel wood, fruits and fodder.

d) Rehabilitation of Degraded Forests

As a third component, the interim report of the **NCA, 1976** suggested reforestation of degraded forests to achieve the following objectives:

1. To grow short rotation fuel and timber species for meeting the requirements.
2. To organize fuelwood supplies at reasonable rates, this will prevent pilferage from neighbouring commercial forests.
3. To tie up degraded forest areas with the nearby rural and semi-urban centers for their requirements of fuelwood.
4. To provide employment.
5. To rehabilitate the degraded forests in the process.

e) Recreation Forestry

Recreation forestry is the practice of forestry with the object of raising avenue/flowering trees and shrubs mainly to serve as recreation forests for the urban and rural population. This type of forestry is also known as **Aesthetic forestry** which is defined as the practice of forestry with the object of developing or maintaining a forest of high scenic value.

DIFFERENTIATE BETWEEN SOCIAL FORESTRY AND AGROFORESTRY

SOCIAL FORESTRY	AGROFORESTRY
1. Social forestry is a plantation made on lands outside conventional forest areas for the benefit of rural and urban communities, with objectives to supply fuel wood to divert cow dung from village hearths to village fields, small timber for housing and agricultural implements and fodder for cattle of the rural population, living far away from the forest area, protection of agriculture by creation of diverse ecosystem, and arresting wind and water erosion.	1. Agroforestry is a sustainable Land management system that increases the overall production, combines agricultural crops, tree crops and forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population.
2. It is thus the forestry of the people, by the people and for the people.	2. Agroforestry is a system which is rather localized in its concept for managing the unit of land for maximizes production of agricultural crop and forest trees complimentary with each other.
3. Planting of trees on massive scale is done on vacant land community land, roadside railway track and even degraded reserve forest.	3. Agroforestry is practiced mostly in farmers' field/own land.
4. Trees and shrubs are to be used to harvest multiple products.	4. It involves integration of two or more than two components in a cultivated land.
5. Social forestry is a short rotation investment.	5. Agroforestry is also short rotation forestry.

LECTURE- 2

LEARNING OBJECTIVE: - TO IMPART KNOWLEDGE ABOUT FOREST DEFINITION, CLASSIFICATION OF FOREST, FOREST TYPES, STATUS OF INDIAN FOREST AND THEIR ROLE IN FARMING SYSTEM

IMPORTANT FOREST DEFINITIONS:

- **General definition-** Forest is defined as 'an area set aside for the production of timber and other forest produce or maintained under woody vegetation for certain indirect benefits which it provides e.g., climatic or protective.'
- **In ecology point of view**, it is defined as a plant community predominantly of trees and other woody vegetation usually with closed canopy.
- **In legal terminology** forest is defined as an area of land proclaimed to be forest under a forest law.

STAND

- Stand is defined as an aggregation of trees occupying a specific area sufficiently uniform in composition, age, arrangement and condition to be distinguishable from the forest on adjoining areas.

CLASSIFICATION OF FORESTS: Forests can be classified on the basis of:

- **Method of regeneration**
- **Age**
- **Composition**
- **Object of management**
- **Ownership and legal status**
- **Growing stock.**

METHOD OF REGENERATION:

- **High forest:** Forest regenerated from seed
- **Coppice forests:** Forests regenerated by vegetative means such as coppicing shoots or root suckers

AGE:

- **Even aged or regular forest**s: Forest composed of even-aged woods and applied to a stand consisting of trees of approximately the same age. Differences up to 25% of the rotation age may be allowed.
- **Uneven aged or irregular forest:** Forest composed of trees of markedly different ages and applied to a stand in which individual stem vary widely in age.

COMPOSITION:

- **Pure forest** is defined as a forest composed of almost entirely of one species usually to the extent of not less than 80%.
- **Mixed forest** is defined as a forest composed of trees of two or more species intermingled in the same canopy.

Plate 2.1 Pure Forest of *Cedrus deodara*

Plate 2.2 Mixed Forest

OBJECTS OF MANAGEMENT:

- **Production forest**: Forest managed primarily for its produce'. It is also sometimes referred to as national forest, i.e., a forest which is maintained and managed to meet the needs of the defence, communication, industry, and other general purposes of public importance'.

- **Protection forest:** An area wholly or partly covered with woody growth, managed primarily to regulate stream flow, prevent erosion, hold shifting sand or to exert any other beneficial influence'.

- **Farm forest:** Forest raised on farms and its adjoining area either as individual scattered trees or a collection of trees to meet the requirement of fuel and fodder of the farmers and to have a beneficial influence on agriculture.

- **Fuel forest:** Forest raised on village waste land to supply fuel, small timber, fodder, etc., to the village communities living far away from Government forest.

- **Recreational forest**: Forest which is managed only to meet the recreational needs of the urban and rural population.

OWNERSHIP AND LEGAL STATUS:

- **State forest** is a 'forest owned by state'. On the basis of legal status, state forests are further classified as:

  - ❖ R**eserved forest** is 'an area so constituted under the Indian forest Act 1927 or other forest law'.

  - ❖ **Protected forest:** An area subject to limited degree of protection under the provision of chapter IV of the Indian Forest act 1927'.

  - ❖ **Village forest:** State forest assigned to a village community under the provision of the Indian Forest Act 1927'.

  - ❖ **Communal forest:** Forest owned and generally managed by a community such as a village, town, tribal authority or local government, the members of which share the produce'.

  - ❖ **Panchayat forest:** Any forest where management is vested in a village panchayat (i.e., a body of men elected by the villagers from among themselves for specific administrative or other purposes pertaining to the village)'.

GROWING STOCK:

- **Normal forests:** Forest which for a given site and given objects of management is ideally constituted as regard growing stock, age class distribution and increment and from which the annual or periodic removal of produce is equal to the increment can be continued indefinitely without endangering future yield.

- **Abnormal forest:** is the one in which the quantity of material in the growing stock is in deficit or in excess or in which the relative proportion of the age or size classes are defectives.

PRESENT STATUS OF INDIAN FORESTS (2009)

- The forest cover of the country as per 2007 assessment is **690,899km^2/69.09 mha** which is **21.02 percent** of the geographical area of the country.
- Very dense forest constitutes **83,510 km^2/ 8.35 million ha (2.54%),**
- The moderately dense forest **319,012 km^2/ 31.90 million ha (9.71%)** and
- Open forest constitutes **288.377 km^2/28.84 million ha (8.77%)**
- The scrub accounts for **41,525 km^2/4.15 million ha (1.26%).**
- Mangrove: **4639 km^2/0.46 million ha (0.14%)**
- Excluding the area (**18.31 million ha**) above tree line, the forest cover of the country comes of **22.26 per cent**
- Reportedly, hills and tribal districts, especially the North-Eastern (NE) states, contributed significantly to this increase.
- Madhya Pradesh has largest area under forest cover followed by Arunachal Pradesh, Chattisgarh, Orissa and Maharashtra
- Mizoram has maximum proportion of geographic area under forest cover followed by Nagaland
- North-East region accounts for **25.11 per cent** of forest cover
- Native forests in India are disappearing at a rate of up to **2.7 per cent per year**
- **Very dense forest -** All lands with tree cover of canopy density of 70% and above
- **Moderately dense forest -** All lands with tree cover of canopy density between 40% and 70%
- **Open forest -** All lands with tree cover of canopy density between 10% and 40%
- **Scrub -** Degraded forest lands with canopy density less than 10%
- **Non-forest –** Any area not included in the above classes

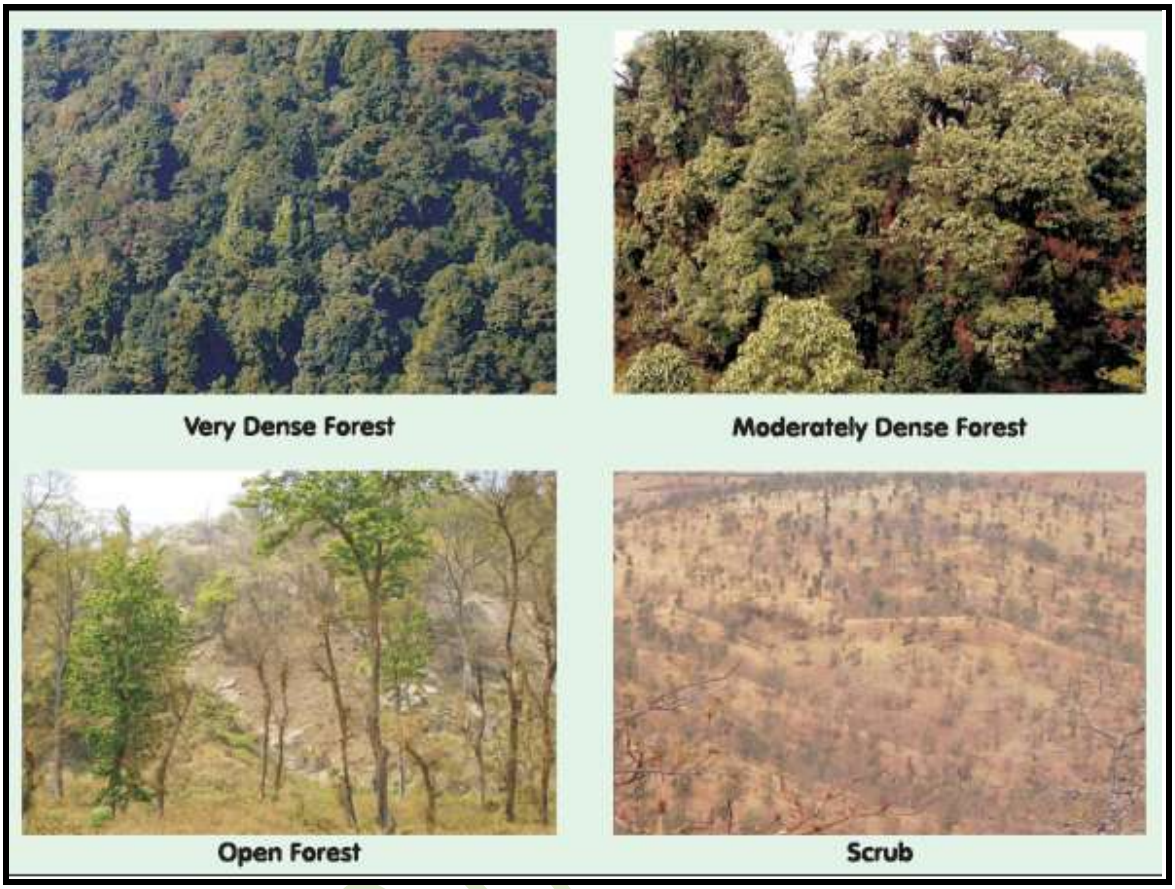

Plate 2.3 Pictorial illustration of different forest cover classes

FORESTS TYPES OF INDIA

Champion and Seth (1967) classified forests of India into 5 major groups and further its is classified into 16 type groups

MAJOR GROUPS

1. **Tropical Forests**
2. **Montane Subtropical Forests**
3. **Montane Temperate Forests**
4. **Sub-alpine Forests**
5. **Alpine scrub**

1. **Tropical Forests:** This group has seven group type such as

a) Wet Evergreen Forest
e) Dry Deciduous Forest

b) Semi-evergreen Forest
c) Moist Deciduous Forest
d) Littoral and Swamp Forest
f) Thorn Forest
g) Dry Evergreen Forest

2. **Montane Subtropical Forests:** This group has three group type
   a) Broad-leaved Hill Forest
   b) Pine Forest
   c) Dry Evergreen Forest
3. **Montane Temperate Forests:** This group has three group type
   a) Montane Wet Temperate Forest
   b) Himalayan Temperate Forest
   c) Himalayan Dry Temperate Forest
4. **Sub-alpine Forests:**
   a) Sub-alpine Forest
5. **Alpine scrub:** This group has two group type
   a) Moist Alpine Scrub
   b) Dry Alpine Scrub

ROLE OF FORESTS IN FARMING SYSTEMS

Forests are known as the world's air-conditioner and the earth's blanket. Without forests, this world would be an inhospitable place to live in. Forests play an important role in environmental stability and provide a variety of benefits to the economy. Of all the ecosystems, forests are the largest, most complex and self-perpetuating. The maintenance of forests is vital for all sections of society regardless of their stage of development. Forests perform various functions. Some of these functions are:

1) **Productive**
2) **Protective**
3) **Ameliorative**
4) **Recreational and**
5) **Developmental**

1) Productive functions of the forest

Forests are valuable natural resources. The goods provided by forests are of immense importance. Wood is a major forest produce and is used extensively for various purposes. In

India, most of the wood produced is used for construction of houses, agricultural implements, bridges, sleepers, etc.

Wood is a universal fuel. For thousands of years, until the advent of coal, oil, gas, electricity, etc., wood constituted man's chief source of fuel. Even today more than half of the total world consumption of wood is for fuel. Wood remains the major source of domestic fuel in India. Out of the total requirement of 201 million tones fuelwood, 103 million tonnes is met from the forest areas (including plantations), which constitutes nearly 51 percent of the total requirement, and the balance 98 million tonnes from farm forestry sector including plantation on common land.

Forests provide raw material to a large number of industries, e.g., paper and pulp, ply board and other boards, saw-mill, furniture, packing cases, matches, toys, etc.

Out of 64 million m^3 timber demand, nearly 31 million m^3 comes from farm forestry and other woodlands and 12 million m^3 from forests. The balance 21 million m^3 is removed from plantations and from natural forests, largely (70%) as small timber to meet the domestic need.

A large number of non-wood products are also obtained from forests. These are commonly called minor forest products, not because they are of minor significance, but because they are harvested in smaller quantities. Some of the important minor forest products are as under:

a. Fibers and flosses
b. Grasses and bamboos
c. Essential oils
d. Oilseeds
e. Tans and dyes
f. Gums and resins
g. Drugs, spices and insecticides
h. Tendu and other leaves
i. Edible products
j. Lac and other products
k. Fodder and grazing

2) Protective and ameliorative functions of forest

i. Forests play a significant role in maintaining the CO_2 balance in the atmosphere. Without sufficient forest cover, all the CO_2 released in the atmosphere will not be utilized, resulting in a higher percent of CO_2 in the atmosphere. This, according to scientists, will result in warming of the world temperature, disturbance in the climate, melting of polar ice caps, increase in sea levels, etc. The CO_2 percent in the atmosphere has already reached 0.042% against the normal of 0.030%. If this increases continuously, higher temperature and other disturbances on the earth may bring unimaginable miseries to mankind.

ii. Forests increase local precipitation by about 5 to 10% due to their orographic and microclimate effect and create conditions favourable for the condensation of clouds.

iii. Forests reduce temperature and increase humidity. The temperature in forests is 3^0 C - 8^0 C less than in adjoining open areas. Reduced temperature makes life comfortable. It also reduces evaporation losses. The effect of forests on temperature is not limited to forests areas; it extends far beyond the boundaries of the forests.

iv. Forests maintain the productivity of the soil through adding a large quantity of organic matter and recycling of nutrients. The leaves of trees are used as manure. Supply of firewood from forests releases dung for use, as manure.

v. Tree crowns reduce the violence of rain and checks splash erosion. Forests increase the infiltration and water-holding capacity of the soil, resulting in much lower surface run-off. This in turn results in checking of soil erosion.

vi. Forests check floods. Forests conserve both soil and water. Forests prolong the water cycle from its inception to the final disposal as run-off into streams and ocean. The longer the water retained in the land, the greater is its usefulness in nurturing crops and trees, and in maintaining a regular supply of water in streams throughout the year. Forests increase subsurface run-off which is much slower than surface run-off and the sub-surface run-off does not cause erosion.

vii. Forests and trees reduce wind velocity considerably. Reduction of wind velocity causes considerable reduction in wind erosion, checks shifting of sand dunes and halts the process of desertification.

viii. Forests and trees provide a shelterbelt and wind breaks effect which is beneficial to agricultural crops, particularly in arid and semi-arid areas, and increase in agricultural production.

3) Recreational and educational function of forest

i. Forests provide recreational facilities to the people. A large variety of trees and shrubs, animals and birds attract a large number of people towards them. National parks and sanctuaries rich in flora and fauna are visited by a large number of people every year.

ii. Forests provide an experimental area and laboratory for college and university students. Forests provide sites for ecological studies.

iii. Forests have a natural healing effect for a number of diseases. Most of the sanatoria are found in a forested locality.

4) Developmental functions of forest

i. Forests provide employment to a large number of people. Almost all forestry activities are labour intensive and provide considerable employment in primary and secondary sectors.

ii. Forests and various forest activities help tribals to improve their socioeconomic condition through collection, processing and marketing of various forest products and by providing gainful employment. Forestry is an important activity in an alleviation programme.

iii. Forests provide a good sum as revenue to the government which is used for various developmental works. During 1985, forests provide revenue worth.

iv. Forests help in biological rejuvenation of soils. Trees through their sturdy root structures open the soil; improve it by adding organic litter or humus rendering it hospitable to useful micro and macro flora and fauna.

v. Trees provide subsistence products, like fodder and other non-wood forest products nearly 30% of the fodder requirement of the country comes from the forest areas. There is removal to the extent of 145 million tonnes of dry fodder and 178 million tonnes of green fodder annually from the forest areas.

vi. In semi-arid regions trees increase soil productivity and land sustainability through nutrient recycling and by providing mulch and shade for crops, thus complement agricultural production.

vii. The most widespread benefit from keeping trees on farms is the soil enriching effect of trees and protection against erosion.

viii. Trees are planted on farm boundaries, or inter-cropped with field crops with a view to get supplementary income from trees without much loss of the main crops.

ix. Homestead plantation increases overall income from land.

x. Where income from agriculture is uncertain and inadequate and there is little possibility for farmer to seek work outside the village; in such conditions, even small farmers shift their lands to trees, which demand less labour and concentrate on wage labour for meeting their immediate consumption needs.

xi. Where trees substitute agricultural crops for increasing total profits from land.

LECTURE-3

LEARINING OBJECTIVE: TO KNOW ABOUT DIFFERENT AGROFORESTRY SYSTEMS, SUBSYSTEM, PRACTICES, AFS CLASSIFICATION, AFS ON NATURE OF COMPONENTS

Different types of agroforestry systems exist in different parts of the world. These systems are highly diverse and complex in character and function. Classification of agroforestry system is necessary in order to provide a framework for evaluating the system and developing action plan for their improvement. Several criteria can be used in classifying them but most common includes **the system structure**, **function**, **socioeconomic scale of management, ecological spread etc.** According to the potential, there are many different systems of agroforestry. In agroforestry the terms like system, sub-system and practices are commonly used. Therefore, these terms require proper definitions in agroforestry languages:

System:

- System refers to a group of physical components, i.e. an assemblage of objects connected or related in such a manner so as to form and/or act as a unit; e.g. ecosystem which consists of living organism and their non-living environment with which they are inseparably interrelated.
- In land use terms, a system refers to a type of land use specific to an area and described according to its biotechnical composition and arrangement, level of technical management of socio-economic features; e.g. rice production system, plantation crop systems.

Sub-system:

- Sub-system indicates a lower order hierarchy of the system.
- It refers to a part of system, with more or less restricted role, content and complexity than the system itself.
- A sub-system produces a defined 'basic needs' as its major output, so that there can be a food sub-system, an energy production sub-system and cash sub-system.

Practices:

- Practices in agroforestry denote specific land management operations of any nature, carried out on a farm or other management unit.
- Such practices are involved in the constitution and maintenance of an agroforestry system; e.g. alley cropping, boundary plantations of trees and shrubs, shelterbelts and windbreaks, etc.

Why classification:

- It include logical way of grouping the major factors on which production of the system will depend
- It indicate how system is managed
- It offer flexibility for regrouping the information
- We usually understood and readily handled

CRITERIA /BASIS FOR AGROFORESTRY SYSTEM CLASIIFICATION

Combe (1982) proposed 24 agroforestry systems based on three type of association of the trees with crops, with pastures and with both crops and pastures); two major functions of the tree components (production and protection); two spatial arrangements (regular and irregular); and two types of temporal association (temporary and permanent).

The most obvious and easy-to-use criteria for classifying agroforestry systems are the spatial and temporal arrangement of components, the importance and role of components, the production aims or outputs from the system, and the social and economic features. They correspond to the systems' structure, function (output), socioeconomic nature, or ecological (environmental) spread. These characteristics also represent the main purpose of a classification scheme. Therefore agroforestry systems can be categorized according to these sets of criteria:

- Structural basis
- Functional basis
- Socioeconomic basis
- Ecological basis

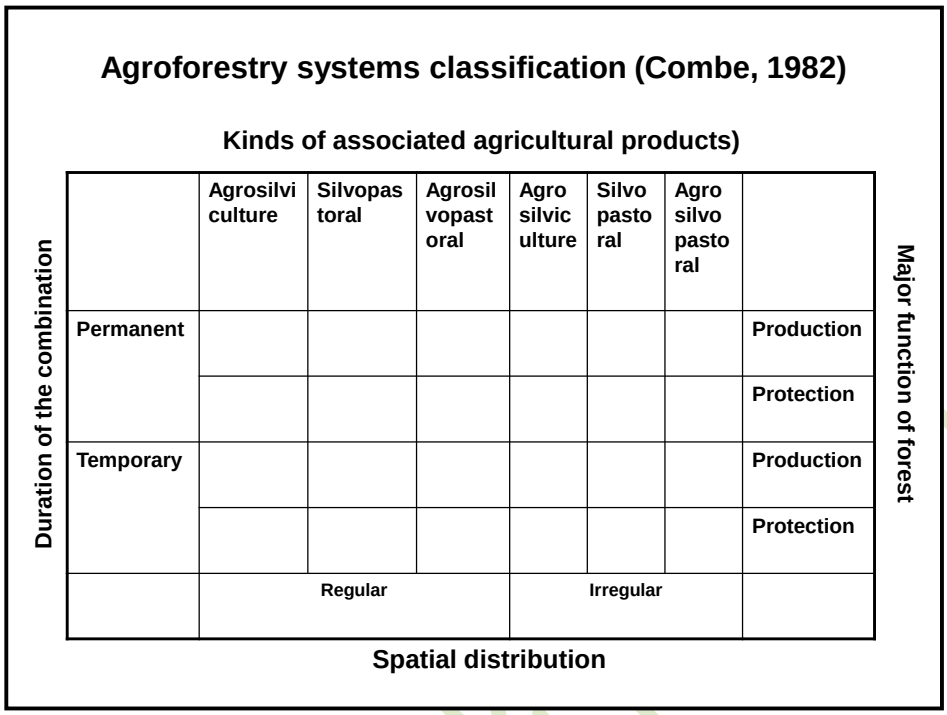

Fig. 3.1(a) Agroforestry systems classification, Combe (1982)

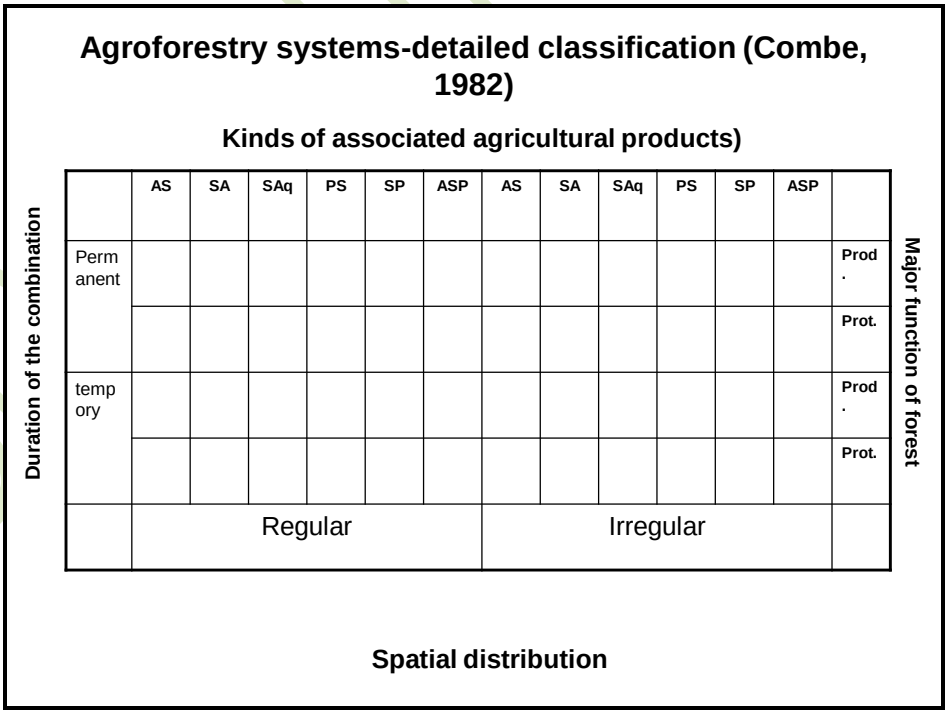

Fig. 3.1(b) Agroforestry systems classification, Combe (1982)

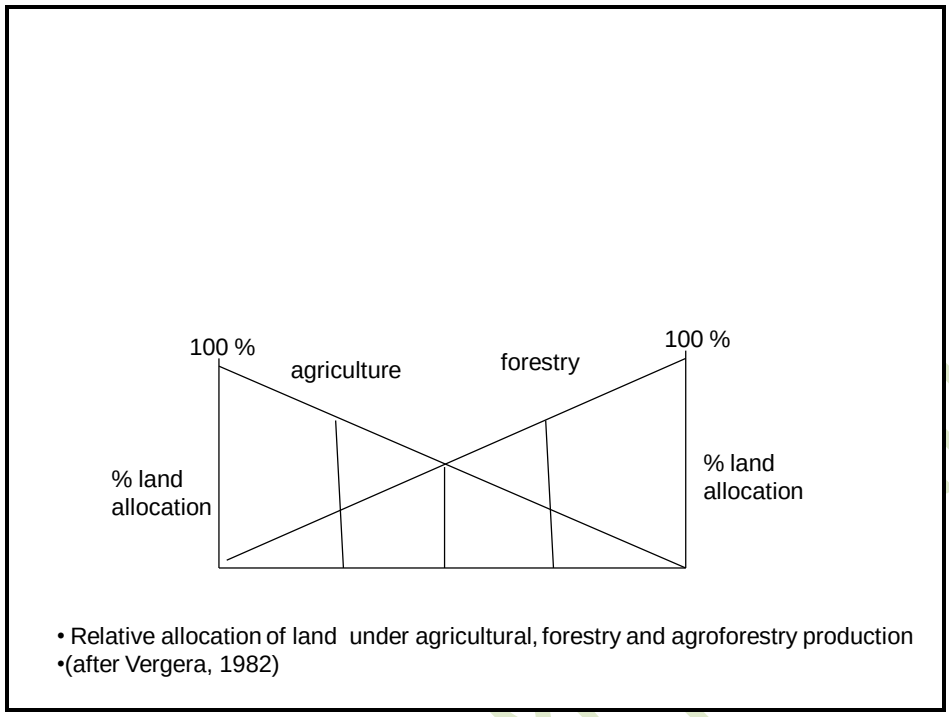

Fig. 3.2 Agroforestry system on relative allocation of land for components

- Vergera (1982) considered the relative allocation of land, trees, crops, pastures in various agroforestry systems.

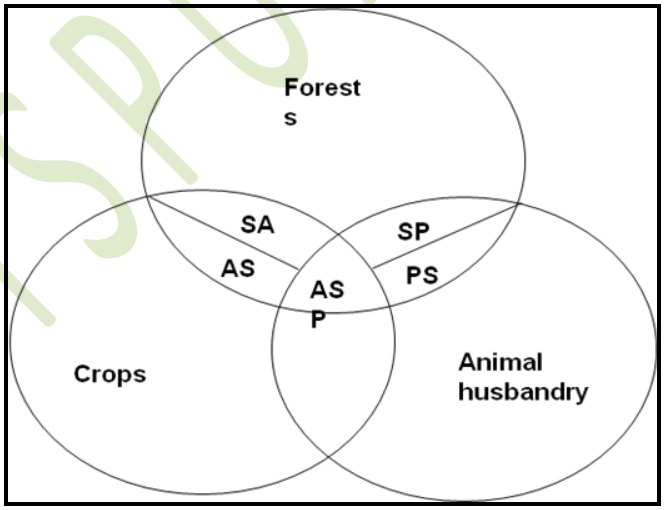

Fig. 3.3 Agroforestry systems on basis of relative dominance of components

- Tejwani (1987) suggested a classification which among the other things also took into account relative dominance of trees or crops/pastures

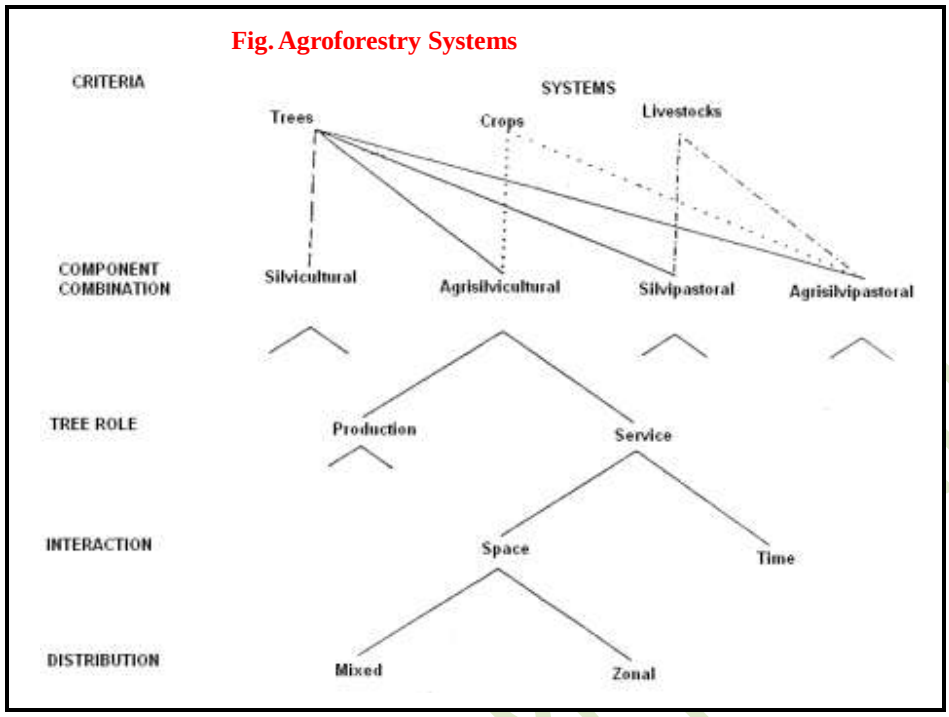

Fig. 3.4 Agroforestry systems based on different criteria

CLASSIFICATION OF AGROFORESTRY SYSTEMS (NAIR, 1985)

- ***Structural basis:*** refers to the composition of the components, including spatial arrangement of the woody component, vertical stratification of all the components, and temporal arrangement of the different components. Hence on the basis of structure agroforestry system can be grouped into two categories.

A) Nature of components

B) Arrangement of components

A) **Nature of components:** Based on nature of component agroforestry systems can be classified into following categories

- Agrisilviculture systems/ silviagriculture/ agrosilviculture
- Silvopastoral systems/ silvipastoral
- Agrosilvopastoral systems/ agrisilvipastoral
- Other systems

- Note: Nomenclature of the system depends upon the prime importance of the component and the component given lot of space placed first in any agroforestry system for eg. Agrisilviculture in which prime component is agriculture crop.
- Agrosilviculture has a wide applicability and it covers in its scope integration of different components of farming system for eg. Vegetables, pulses, oil seed crops, cereals etc.
- Whereas agrisilviculture restricted only to integration of cereals with the tree crop

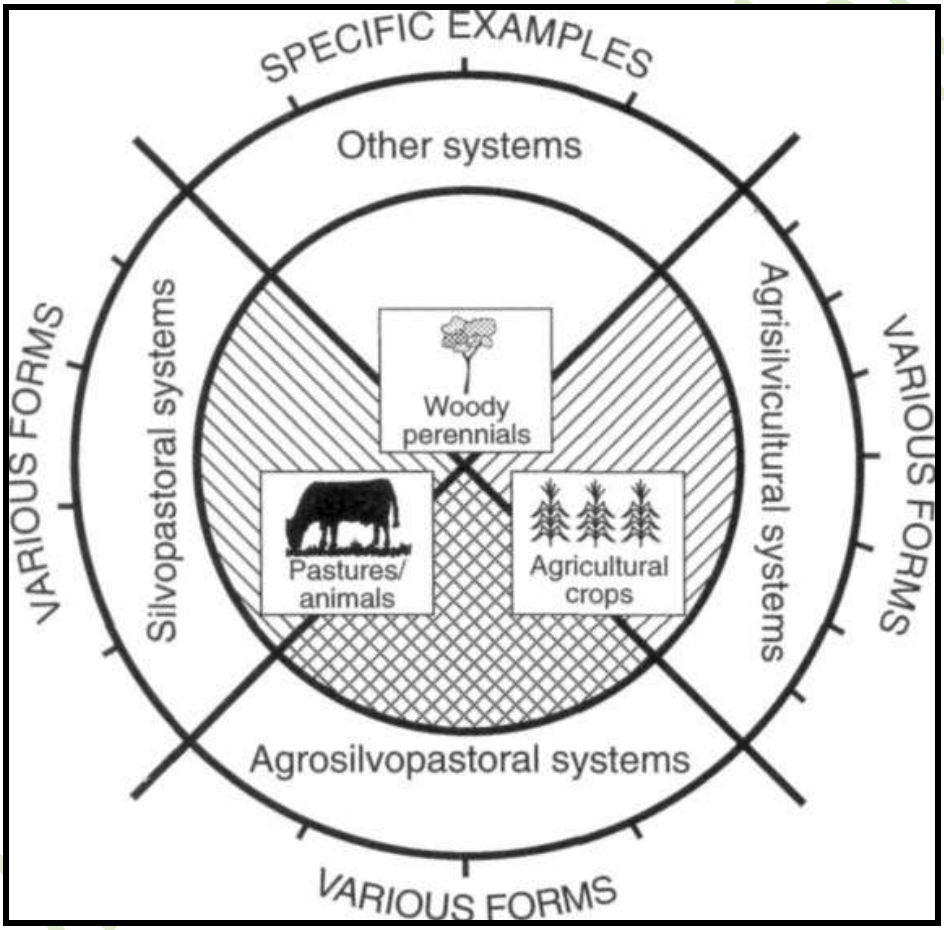

Plate 3.1 Classification of agroforestry systems on the basis of nature of components

I. Agrisilviculture/Silviagriculture/Agrosilviculture

This system involves the conscious and deliberate use of land for the concurrent production of agricultural crops including tree, crops and forest crops. Based on the nature of the components this system can be grouped into various forms:

a) Improved fallow species in shifting cultivation
b) The Taungya system
c) Multispecies tree gardens
d) Alley cropping (Hedgrow intercropping)
e) Multipurpose trees and shrubs on farmlands
f) Crops combinations with plantation crops
g) Agroforestry for fuelwood production
h) Shelter belts
i) Wind breaks
j) Soil conservation hedges etc.

a) Improved fallow species in shifting cultivation:

Shifting cultivation:

- It is prevalent in many parts of Africa, Latin America, South-East Asia and Indian subcontinent.
- In India it is prevalent in Assam, Meghalaya, Jharkhand, Manipur, Orissa, Nagaland, Chattisgarh, M.P., Arunanchal Pradesh, Andhra Pradesh, Mizoram, Tripura, Kerala, West Bengal, Sikkim.
- It is known as ‘jhuming’ in North-east, ‘khallu / kurwa’ in Jharkhand and ‘dahiya’ or ‘podo’ in Orissa, Andhra Pradesh.
- In this system, forest patch is selected and cleared felled. The herbs, shrubs and twigs and branches (slashed vegetation) are burnt .Cultivation of crops is done for a few years until soil fertility declines. The site is than abandoned (fallow period) and new patch is selected for cultivation of crops. The site is again cultivated after giving rest for few years.
- Earlier the fallow cycle was of 20–30 year. However, due to increasing requirement for cultivation of land due to population pressure, fallow period has reduced from 25–30 years to 2–3 years which has broken down the resilience of ecosystem and the land is increasingly deteriorating. Thus now shifting cultivation has become source of ecological degradation, soil erosion and converting good forests into wastelands.

Plate 3.2 Shifting cultivation

Effect of shifting cultivation

- Deforestation and denudation of hill slopes-in secondary succession, area is occupied by weeds, useless shrubs etc
- Soil erosion which leads to soil and nutrient losses, silting of reservoirs and streams, reduction in water-yield and landslips and landslides
- Shifting cultivation adversely affects cation exchange capacity and physical properties of soil. It leads to lowering of organic matter and lowering the total quantity of sesquioxides, iron, aluminum, calcium, potassium, phosphorus, etc.
- Increases soil pH and reducing microbial activity
- More weed growth and lower crop yield
- No opportunity for infrastructural development

Controlling shifting cultivation

- Motivate public for permanent agriculture by opening demonstration centers for improved agricultural practices, good quality seed, manuring, irrigation, weeding use of improved tools, terracing etc.
- Earning goodwill of local people: By engaging them in forest work and training them to undertake shifting cultivation on scientific lines.

- Arable land can be provided to the tribals for carrying out agriculture and also to settle in the area; a few schemes are being implemented under integrated tribal development programme
- Legal measures: on steep slopes, near to roadside etc
- Using land according to its capability
- Provision of alternative management
- Development of animal husbandry and dairy farming
- Training of artisans and development of handicrafts
- Employment in forest works and other industries
- Providing communication facilities
- Providing economic assistance for houses and agriculture operations

Improved fallow species in shifting cultivation:

- Fallows are crop land left without crops for periods ranging from one season to several years.
- The objective of improved fallow species in shifting cultivation is to recover depleted soil nutrients. Once the soil has recovered, crops are reintroduced for one or more season.
- The best species for the fallow system should induce good nitrogen fixation in the soil.
- The main aim of the fallow is to maintain or restore soil fertility and reduce erosion; some plants can be introduced primarily for their economic value.
- Plants included in improved fallows should be compatible with future crops, free of any negative physical or chemical effects on the soil and not in competition with the crops to be planted later on the same site.

b) Taungya System of cultivation:

- The taungya system was used primarily as an inexpensive means of establishing timber plantations but is finally a recognized AF system.
- The taungya (taung = hill, ya = cultivation) is a Burmese word coined in Burma in 1850. The system was introduced to India by Brandis in 1890 and the first taungya plantations were raised in 1896 in North Bengal.

- It was introduced to S Africa in 1887 and was taken to Chittagong and Sylhat (Now in Bangladesh) in 1870.
- In India it started in 1896 in North Bengal. In 1890, it was introduced to Coorg in Karnataka. Regular plantation however started in North Bengal in 1911 for raising Sal plantations and in 1912, extended for raising Teak. In 1923 it was adopted in UP for raising Sal plantations.
- It is still practiced in the states of Kerala, West Bengal, Orissa, Karnataka and the north-eastern hill region.
- This is a modified form of shifting cultivation in which the labour is permitted to raise agri-crops in an area but only side by side with the forest species planted by it. The practice consists of land preparation, tree planting, growing agricultural crops for 1-3 years, until shade becomes too dense, and then moving on to repeat the cycle in a different area. A large variety of crops and trees, depending on the soil and climatic conditions, are grown in India. In fact this system was introduced to raise forest plantations, but finally became recognized agroforestry system.

Types of Taungya:

i. **Departmental Taungya:** Under this, agricultural crops and plantation are raised by the forest department by employing a number of labourers on daily wages. The main aim of raising crops along with the plantation is to keep down weed growth.

ii. **Leased Taungya:** The plantation land is given on lease to the person who offers the highest money for raising crops for a specified number of years and ensures care of tree plantation.

iii. **Village Taungya:** This is the most successful of the three taungya systems. In this crops are raised by the people who have settled down in a village inside the forest for this purpose. Usually each family has about 0.8 to 1.7 ha of land to raise trees and cultivate crops for 3 to 4 years.

Table 3.1: Trees and crops grown in Taungya

State	Tree crop	Associated agricultural crops
U.P.	*Shorea robusta, Tectona grandis Acacia catechu, Dalbergia sisso, Eucalyptus spp. Populus spp.*	Maize, paddy, sorghum, pigeon-pea, soyabean, wheat, barley, chick-pea, rape-see and miscellaneous
Andhra Pradesh (AP)	*Anacardium occidentale, Tectona grandis, Bombax ceiba, Bamboo, Eucalyptus spp.*	Hill paddy, groundnut, sweet potato
Kerala	*Tectona grandis Bombax ceiba Eucalyptus spp.*	Paddy, tapioca, ginger, turmeric, etc.
Assam	*Shorea robusta, S assamica*	Paddy
Tamil Nadu	*Tectona grandis, Santalum album Tamarindus indica, Acacia nilotica Acacia mearnsii ,Ceiba pentandra Cashew, Rubber, Bamboo*	Millet, pulses, groundnut, cotton
Andaman and Nicobar Islands	*Pterocarpus dalbergioides*	Sugar-cane, maize
Maharashtra	*Tectona grandis, Acacia nilotica*	Sunhemp, jute, mesta, sunflower, castor etc.
Tripura	*Shorea spp., Schima spp., Michelia spp.*	Paddy, maize etc
West Bengal	*Tectona grandis, Shorea robusta Schima wallichii, Cryptomeria japonica, Quercus spp. Michelia doltsopa*	Paddy, maize, millets, turmeric, ginger, lady's, finger, pineapple, sunhemp
Karnataka	*Tectona grandis, Santalum album, Cassia siamea*	Paddy, tapioca, etc.

ADVANTAGES OF TAUNGYA:

- Artificial regeneration of the forest is obtained cheaply;
- Problems of unemployment are solved;

- Helps towards maximum utilization of the site;
- Low cost method of forest plantation establishment;
- In every case, highly remunerative to the forest departments;
- Provision of food crops from forest land; and
- Weed, climber growth, etc. is eliminated.

DISADVANTAGE OF THE TAUNGYA:

- Loss of soil fertility and exposure of soil;
- Danger of epidemics;
- Legal problems created;
- Susceptibility of land to accelerated erosion increases; and,
- It is a form of exploitation of human labour

c) Multi-species tree Gardens:

- In this system of agroforestry, various kinds of tree species are grown mixed.
- The major function of this system is production of food, fodder and wood products for home consumption and sale.

d) Alley cropping (Hedge row intercropping):

- Alley cropping, also known as hedgerow intercropping,
- In this perennial, preferably leguminous trees or shrubs are grown simultaneously with an arable crop.
- The trees, managed as hedgerows, are grown in wide rows and the crop is planted in the interspace or 'alley' between the tree rows.
- During the cropping phase the trees are pruned and leaves and twigs are used as mulch on the cropped alleys in order to reduce evaporation from the soil surface, suppress weeds and/or add nutrients and organic matter to the top soil.
- The primary purpose of alley cropping is to maintain or increase crop yields by improvement of the soil and microclimate and weed control. Farmers may also obtain

tree products from the hedgerows, including fuelwood, building poles, food, medicine and fodder, etc.

Plate 3.3 Alley cropping

Layout of Alley:

- The position and spacing of hedgerow and crop plants in an alley cropping system depend on plant species, climate, slope, soil conditions and the space required for the movement of people.
- Ideally, hedgerows should be positioned in an east to west direction so that plants on both sides receive full sunlight during the day.
- The spacing used in fields is usually 4 to 8 meters between rows and 25 cm to 2 meters between trees within rows. The closer spacing is generally used in humid areas and the wider spacing in sub-humid or semi-arid regions.

Plate 3.4 (a) Alley cropping

Plate 3.4 (b) Alley cropping

Characteristics of species for hedgerow intercropping: Alley cropping usually includes leguminous trees to improve soil fertility through nitrogen fixation; hence an ideal alley cropping tree or shrub species should have following characteristics:

- It should have a sparse, small crown to permit sunlight penetration into the cropped area

Plate 3.5 Hedgerow intercropping

- It should re-sprout rapidly after pruning, coppicing, pollarding or lopping.
- It should form a deep taproot system so that it takes moisture and nutrient from deeper layers and will not compete with agricultural crops.

- It should have shallow lateral roots that are easily 'pruned' by ploughing along the hedgerow, without serious damage to the plants.
- Fast decomposition rate of leaf litter.
- Ideally, trees and shrubs used for alley cropping should fix nitrogen.
- Trees/shrubs should be non-exacting in nature.

Promising species

- *Gliricidia sepium, Flemingia macrophylla, Leucaena, Calliandra calothyrsus, Erythrina subumbrans, Albizia saman, Pithecellobium dulce, Paraserianthes falcataria, Acacia spp., Paraserianthes falcataria and Cajanus cajan*.

ADVANTAGES

- Improved crop performance due to the addition of nutrients and organic matter into the soil/plant system,
- Reduction of the use of chemical fertilisers,
- Improvement in the physical nature of the soil environment.
- Reductions in erosion losses.
- Provision of additional products such as forage, firewood or stakes when a multipurpose tree legume is used as the hedgerow, and
- Improvement in weed control.

e) Multipurpose trees and shrubs on farmlands:

- In this system various multipurpose tree species are scattered haphazardly or according to some systematic patterns on bunds.
- The major components of this system are multipurpose trees and other fruit trees and common agricultural crops.
- The primary role of this system is production of various trees products and the protective function is fencing and plot demarcation. Examples of multipurpose trees employed in agroforestry are: *Leucaena leucocephala*, *Acacia albida*, *Cassia siamea*, *Casuarina equisetifolia*, *Azadirachta indica*, *Acacia senegal*, *Cocos nucifera,* etc.

f) Crop combinations with plantation crops:

Perennial trees and shrubs such as coffee, tea, coconut and cocoa are combined into intercropping systems in numerous ways, including:

i. Integrated multistory mixture of plantation crops;

ii. Mixture of plantation crops in alternate or other crop arrangement;

iii. Shade trees for plantation crops

iv. Intercropping with agricultural crops.

- Tea (*Camilia sinensis*) is grown under shade of *A. chinensis, A. odoratissim, A. lebbek, A. procera, Acacia lenticularis, Derris robusta, Grevillea robusta, Acacia spp., Erythrina lithosperma, Indigofera tesmanii.*
- *Coffee (Coffea arabica)* is grown under the shade of *Erythrina lithosperma* as temporary shade while, permanent shade trees include *Ficus glomerata, F. nervosa, Albizia chinensis, A. lebbek, A moluccana, A. sumatrana, Dalbergia latifolia, Artocarpus integrifolius, Bischofia javanica, Grevillea robusta.*
- Cacao *(Theobroma cacao)* is grown under the shade of coconut and areca nut, *and Dipterocarpus macrocarpa (in forest*).
- Black pepper *(Piper nigrum*) is grown with support from *Erithrina indica, Garuga pinnata, Spondias, Mangifera, Gliricidia maculate* and *Grevillea robusta.*
- Small cardamom (*Elettaria cardamomum*) and large cardamom (*Ammomum subulatum*; *A. aromaticum*) grow in forests under temporary shade tree of *Mesopsis emini.*.
- Large cardamom is grown under the shade of natural forest as well under planted shade treesviz., *Alnus nepalensis, Schima wallichii*; *Cinchona spp*.; *Lagerstroemia spp., Albizia lebbek*; *Castanopsis tribuloides*; *C. hystrix*; *C. indica*; *Terminalia myriocarpa*; *Bischofia javanica*.

g) Agroforestry for fuelwood production:

- In this system, various multipurpose fuelwood/firewood species are inter-planted on or around agricultural lands.
- The protective role is to act as fencing, shelter belts and boundary demarcation.
- Tree species commonly used as fuelwood are: *Acacia nilotica, Albizia lebbek, Cassia siamea, Casuarina equisetifolia, Dalbergia sissoo, Prosopis juliflora, Eucalyptus tereticornis,* etc.

h) Shelterbelt:

- Shelterbelt is a wide belt of trees, shrubs and grasses, planted in rows which goes right across the land at right-angle to the direction of the prevailing winds to deflect air current, to reduce wind velocity and to give general protection to cultivated areas against wind erosion and desiccating effect of the hot winds in lee-ward side.

- A typical shelterbelt has a triangular cross-section which can be achieved by planting tall trees in the centre, flanked on both sides successively by shorter trees, tall shrubs and then low spreading shrubs and grasses.
- A certain amount of penetrability is desirable in shelterbelts as a result of which the zone of influence is very much greater and the velocity curve shows a smooth, slowly declining trend.
- The width of shelterbelt depends upon local climatic conditions, wind velocity, and the soil type.
- Shelterbelt should be oriented as nearly as possible, at right angles to the prevailing wind In case, where winds blow from different directions, shelterbelt should be raised in quadrangles.

Height and spacing—

- Height of shelterbelt is very important
- As it affects the distance to which protection will be afforded on the lee-ward side.
- Higher the trees forming the shelterbelt, the greater is the zone of influence on the leeward side.
- This affects the spacing of the shelterbelts also. If wind erosion has to be completely controlled, the second belt should be located a little before the place where the wind on the lee-ward side often first shelterbelt assumes damaging velocity.
- Taking 20% reduction in wind velocity as the basis of usefulness of a shelterbelt, effective protection zone extends up to 15 to 20 times the height of the belt.
- In Rajasthan, taking the height of shelterbelt to be about 7.5 m, spacing recommended is 10 times the height, i.e., 75 meters.

Length:

- The length of shelterbelt is an important consideration because at the ends of the shelterbelt eddies are produced resulting in increasing the wind velocity at these places.
- It is because of this that road is not ordinarily allowed to cross a shelterbelt.
- In some of the western countries, shelterbelts have been raised right across the country for the protection they afford

- For shorter shelterbelt, the minimum length of shelterbelt to be most effective is 24 times its height.

Soil Preparation:

- Soil preparation should be done at least a year in advance to build up sufficient reserve of soil moisture
- It may be done either mechanically or by manual labour
- Leguminous crops may be raised for the first few years in between the rows of trees and shrubs for improving the fertility of the soil.

Choice of species:

- The choice of species to be raised in shelterbelt is governed by the climate, soil and topography of the area.
- It is better to raise local species because of their easy establishment.
- Exotics may also be used to improve the efficiency of the shelterbelts.

Characteristics of tree spp. used for shelterbelt:

- The species selected should be non-exacting;
- Fast-growing;
- Wind-firm;
- Drought-resistant;
- Unpalatable to animals;
- It should have a dense crown and low branching habit;
- It should not be leafless at a time when protection is required;
- It should be economically a multipurpose species, i.e., fit for firewood, timber and fodder.

The following species are recommended for creation of shelter belt:

Grasses: *Cenchrus barbatus, Saccharum spontaneum, Saccharum munja, Panicum turgidum, Panicum antidotale.*

Shrubs: *Calotropis procera, Crotolaria burhia, Calligonum polygonoides, Clerodendron phlomoides, Cassia auriculata, Dodonaea viscosa, Jatropha curcas, Leptadenia spartivm, Agave* spp. , *Sesbania aculeata.*

Small trees: *Acacia jacquemontii, Acacia leucophloea, Balanites aegyptiaca, Capparis aphylla, Salvadora oleoides.*

Trees: *Acacia arabica, Acacia senegal, Acacia cyanophylla, Albizzia lebbek, Azadirachta indica, Dalbergia sissoo, Lannea coromendelica, Parkinsonia aculeata, Prosopis cineraria, Prosopis juliflora, Pongamia pinnata, Tecoma undulata, Tamarix articulata, Eucalyptus* spp., *Acacia tortilis.*

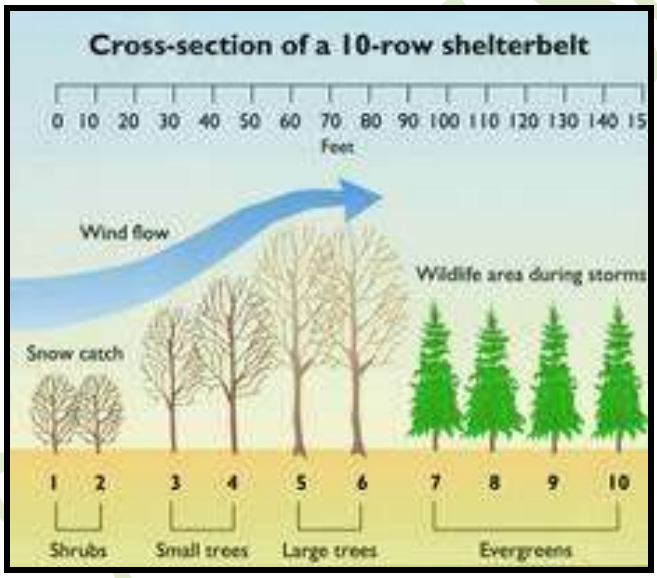

Fig. 3.5 A cross section of 10-row shelterbelts

Method of raising the plants:

- It is better to sow the seeds in polythene bags and plant out the plants so raised.
- For this purpose nurseries should be maintained at site.
- The plant should be regularly watered for one or two years.
- Properly fenced to protect them from browsing cattle.

ADVANTAGES OF SHELTERBELTS:

- Very little research work has been done in our country.

- To find out the benefits of the shelter-belts on yields of agricultural crops, horticultural crops and grasses.
- However, on the basis of research work done in CAZRI, TNAU and abroad, the following advantages of the shelterbelts may be mentioned:

Moderating effect on temperature—

- Shelterbelt has a moderating effect on air and soil temperature by lowering the maximum and raising the minimum.
- Temperature during day time inside the forest is lower evaporation.
- Temperature during night is higher inside the forest than open.

Increase in humidity—

- Shelterbelts increase relative humidity from 1 to 50%.
- There is distinctly perceptible increase in the average relative humidity in the agricultural land protected by shelterbelts

Reduction in evapo-transpiration:

- Shelterbelts reduce evapo-transpiration sufficiently in the zone of their influence.

Increase in soil moisture:

- Shelterbelts increase the moisture content of the soil on the leeward side and delay it's drying up during summer.
- They also increase the underground water supplies by promoting infiltration in the soil.

Reduction in wind velocity and wind erosion:

- Shelterbelts deflect the wind upwards
- Cause considerable reduction in the wind velocity on the leeward side upto a distance of 15 to 20 times the height of the trees forming the shelterbelt.
- As there is considerable reduction in the wind velocity on the leeward side of a shelterbelt, wind erosion is very much reduced.

Increase in agricultural and horticultural crops:

- Shelterbelts increase production of agricultural and horticultural crops.
- Study made in 8 cotton fields in distinctly semi-arid areas of U.S.A. revealed an increase of 17.4% in cotton yield when protection against hot winds was provided by shelterbelts.

- Similar increase in crop yields has been reported from Russia where a shelterbelt of 5 rows increased the oat yield by 25% to 28%.
- Protection of orchards by shelterbelt reduces wind damage and increases fruit yield.
- Studies revealed that even if 0.4 hectare out of 4 hectare orchard is devoted to creation of shelterbelt, the remaining protected 3.6 hectare of orchard yielded about 13.00% more than the unprotected 4 Hectare orchard.
- Similarly, the increase in fodder yield is reported to be as high as 300 - 400%.

Protection of damage to public and private property:

- The shelterbelts hold up the movement of shifting sand
- Save the roads and railway tracks from being covered and otherwise damaged by moving sand dunes.
- They prevent deposition of silt in canals and agricultural fields.

i) Windbreaks:

- Wind break is a protective planting around a garden, a farm or a field to protect it against strong winds.
- It usually consists of 2-3 rows of trees or shrubs, spaced at 0.5 m to 2.5 m apart, depending on the species.

Plate 3.6 Windbreak

j) Soil conservation hedges:

- In this system, the major groups of components are: multipurpose and/or fruit trees and common agricultural species.
- The primary role of multipurpose fruit trees and agricultural species is soil conservation and provision of various tree products.
- The following tree species are used for soil conservation: *Grevillea robusta, Acacia catechu, Pinus roxburghii, Acacia modesta, Prosopis juliflora, Alnus nepalensis, Leucaena leucocephala,* etc.

HORTISILVICULTURE

It is deliberately integration of horticultural trees with timber trees in order to harvest fruits and timber concurrently from single unit of land. Timber trees are planted on bunds of the orchards acts as windbreak thus protect orchard from high winds.

HORTISILVOPASTORAL

In this system various improved leguminous grasses are grown in orchard in order to provide forage to livestock. Trees are planted on the bunds of the orchards. These trees acts as windbreaks and protect horticulture plants from high wind; also provides multiple products.

LECTURE- 4

LEARNING OBJECTIVE: DIFFERENT AGROFORESTRY SYSTEMS, SUBSYSTEM, PRACTICES, AFS CLASSIFICATION, AFS ON NATURE AND ARRANGEMENT OF COMPONENTS (CONTD…)

II. SILVI-PASTORAL SYSTEM (TREES + PASTURE and/or ANIMALS)

- The production of woody plants combined with pasture is referred to as a silvi-pastoral system.
- The trees and shrubs may be used primarily to produce fodder for livestock or they may be grown for timber, fuelwood, and fruit or to improve the soil.
- A silvi-pastroal system is needed in dry areas, in order to meet out the demands of wood and fodder throughout the year. There are three main categories of silvicultural system

A. Protein bank

B. Live fence of fodder trees and hedges

C. Trees and shrubs on pasture land

A. PROTEIN BANK:

- In this system various multipurpose trees (protein rich trees) are planted on or around farmlands and rangelands
- For cut and carry fodder production to meet the fodder requirements of livestock during the fodder deficit period in winter.
- These trees are rich in protein.
- The trees planted in protein banks are…

Grewia optiva, Bauhinia variegata, Morus alba, Artocarpus spp., *Anogeissus latifolia, Cordia dichotoma, Dalbergia sissoo, Eutralobium saman, Zizyphus jujube,* etc.

B. LIVE FENCE OF FODDER TREES AND HEDGES:

- In this system, various fodder trees and shrubs are planted as live fences to protect the property from stray animals
- To protect the farm property from biotic influences.

- The following trees are generally used: *Sesbania grandiflora, Gliricidia sepium, Erythrina abyssinica, Euphorbia* spp., *Acacia* spp. etc.

C. TREES AND SHRUBS ON PASTURE LAND:

- In this system various tree and shrub species are scattered irregularly or arranged according to some systematic pattern,

III. AGRISILVOPASTORAL/AGROSILVOPASTORAL SYSTEM (CROPS + TREE + GRASSES/ANIMALS)

This system has been grouped into two subgroups:

A. HOME GARDENS

B. WOODY HEDGE ROWS FOR BROWSING, MULCHING, GREEN MANURING AND SOIL CONSERVATION.

A. HOME GARDENS:

- It is deliberate integration of trees, crop and animals in a same unit of land in some form of spatial and temporal sequence.
- This is one of the oldest agroforestry practices found in high rainfall area of South and South-East Asia.
- In India it is prevalent in Southern states like Kerala, Tamilnadu.
- Also common in North Eastern states like Tripura, Assom, West Bengal and part of Islands of Andaman and Nicobar.
- In India it is a common practice to plant trees around the habitation.
- It is also known as multilayered AFS
- Area of homestead varies from 0.2-0.5ha
- Tall tree/timber tree occupy the top most layer followed by fruit tree.
- Small shrubs also form the parts of home garden.
- Shade loving vegetables find their place in the ground layer.
- Trees provide timber, fruits and also support climber such as pepper, cucurbits, clove, yam, sweet potato, colocasia etc.
- Pineapple is a common fruit grown in home garden.

- In hills, the common spp. for home gardens is *Grewia optiva*, *Ficus glomerata*, *Juglans regia* and *Punica granatum*.
- In rural areas, fruit trees and commercial tree spp., such as *Acacia* and Neem are of common occurrence in most of the country.
- Cattle and poultry are the main component of homesteads.
- Forage spp. like Stylo, Guinea grass, Guatemala, Napier and *Setaria cephalis* variety Kazungula also find their place in home garden.

B. WOODY HEDGES FOR BROWSING, GREEN MANURING, MULCHING AND SOIL CONSERVATION:

- In this system various woody hedges especially
- Fast growing
- Good coppicing capacity planted in order to
- Browse the animals
- Mulching purpose
- Green manuring purpose
- Soil conservation purpose
- Aim is production of food, fodder, fuel-wood and soil conservation

IV. OTHER SPECIFIED SYSTEMS

i) Apiculture with Tree:

- In this system nectar and pollen rich tree/shrubs are planted on the bunds of the farm.
- Some agriculture/oil seed crops are also grown.
- *Mangifera indica, Vitex negundo, Melia azedarach, Azadirachta indica, Prunus salicina, Prunus armeniaca, Rubus ellipticus, Eucalyptus spp., Callistemon lanceolatus, Berberis lycium, Toona ciliata,* etc.
- Main purpose of this system is production of honey.

ii) Aqua-forestry:

- ✓ Aqua-forestry is very common in coastal regions (more evident along Andhra coast).
- ✓ Farmers are cultivating fish and prawn in saline water and growing coconut and other trees on bunds of ponds.
- ✓ These trees help in producing litter-feed to fishery and generate extra income to farmers.
- ✓ Now fish culture in mangroves is also advocated which forms a rich source of nutrition to aquatic life and breeding ground for juvenile fish, prawn and mussels.
- ✓ A well-balanced system of animal husbandry including goatry, poultry, duck-farming, turtles and fishes in the small ponds in home-gardens make a balanced system of high moisture, energy and nutrient-use efficiency per unit area.
- ✓ The leaves of many leguminous trees viz. *Gliricidia sepium, Leucaena, Moringa oleifera, Acacia nilotica* etc. have been found to serve as good fish feed when offered as pellets and improved its productivity.
- ✓ Area is enclosed with earth embakements.
- ✓ Inside the embakement, system of ridges and canals is created. Rain water is collected by making bunds which helps in growing of tree species.

iii) Multipurpose Wood Lots:

In this system special location-specific MPTs are grown mixed or separately planted for various purposes such as wood, fodder, soil protection, soil reclamation, etc.

B) AGROFORESTRY SYSTEMS BASED ARRANGEMENT OF COMPONENTS

Arrangement of component refers to the plant component of the system even in agroforestry system involving animal the management of such animal according to definite plan such as rotational grazing scheme is in consideration more of the plant than animal. Such plant arrangement in multi species combination can involve dimension, space and time.

- **Spatial arrangement of plant in agroforestry mixture can result**
  - Mixed dense, e.g., homegardens
  - Mixed sparse, e.g. most systems of trees in pastures
  - Zonal-microzonal, macrozonal

Spatial or zonal agroforestry varies from microzonal (such as alternate rows of plant components) to macrozonal arrangements. An extreme form of the zonal arrangement is the boundary planting of trees on edges of plots for fruits, fodder, fuel wood, fencing, soil protection and windbreak.

- **Temporal arrangement of plant in agroforestry systems can take various forms such as**
  - **Coincident**
    When two component woody and non woody components occupy the land together as coffee under shade tree and pasture under shade trees
  - **Concomitant**
    When two component woody or non woody stays together for some part of life as in taungya
  - **Intermittent (Space dominated)**
    When annual crops are grown with perennial crops such as paddy with coconut
  - **Interpolated (Space and time dominated)**
    When different components occupy space during different time as in home garden
  - **Overlapping** Black and rubber
  - **Separate (time dominated)**
    When component occupy space during separate time such as improved fallow species in shifting cultivation

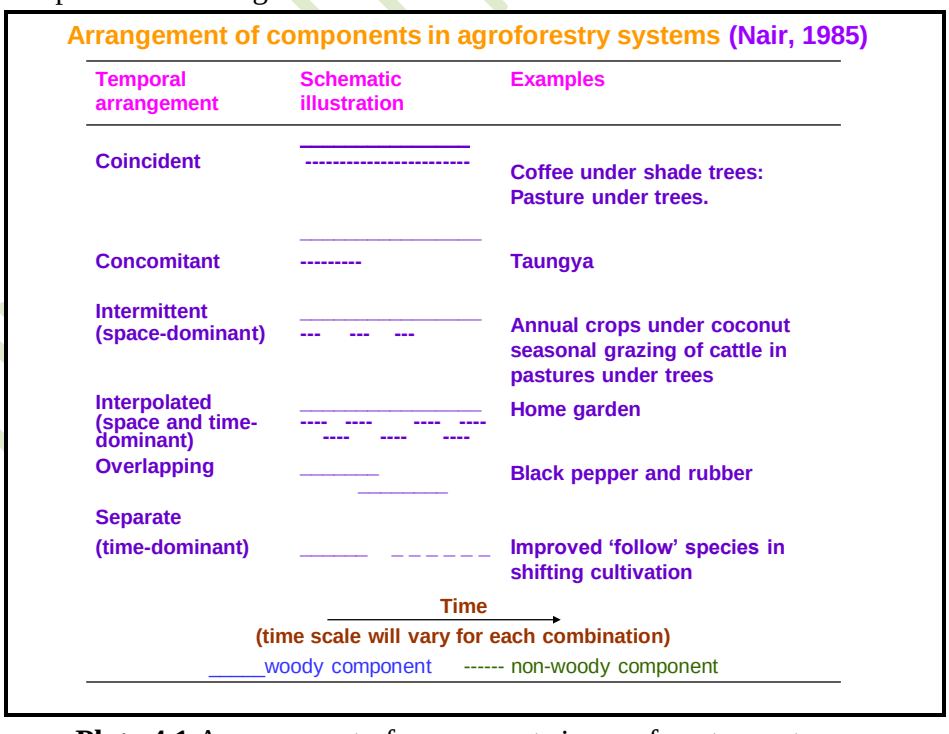

Plate 4.1 Arrangement of components in agroforestry systems

- ***Functional basis:*** refers to the major function or role of the system, usually furnished by the woody components (these can be of a service or protective nature, e.g., windbreak, shelterbelt, soil conservation).

– Production
– Protection

- ***Socioeconomic basis:*** refers to the level of inputs of management (low input, high input) or intensity or scale of management and commercial goals (subsistence, commercial, intermediate).

– **Commercial agroforestry systems** aim at the production of a saleable output (for example, commercial tree plantations with under planting of food crops)
– **Intermediate agroforestry systems** fall between commercial and subsistence scales of production and management
– **Subsistence agroforestry systems** are directed toward satisfying basic needs, and are managed mostly by the owner/occupant and his family. Cash crops, including sale of produce surplus are only supplementary

- ***Ecological basis:*** refers to the environmental condition and ecological suitability of systems, based on the assumption that certain types of systems can be more appropriate for certain ecological conditions; i.e., there can be separate sets of agroforestry systems for arid and semiarid lands, tropical highlands, lowland humid tropics, etc.

LECTURE-5

LEARNING OBJECTIVES: ENERGY PLANTATION, CHARACTERISTICS OF TREE SPP. FOR ENERGY PLANTATION, DIFFERENT ENERGY PLANTATION SPECIES & ADVANTAGES OF ENERGY PLANTATION

Introduction

- India is one of the world's 2nd largest populated country.
- India has huge human population of 125 crore.
- Most of the population (75%) residing in rural area which totally depends upon forest to meet out their energy requirement.
- The demand for fuelwood in India is increasing day by day.
- India's current firewood consumption is more than 133 million tonnes; most of it is being used in cooking. To cook 1 kg of food 1.2 kg of firewood is required.
- It clearly indicates that India should produce more wood than food if it is to be cooked before it is consumed. The electricity can also be generated by dried wood.
- According to estimate 400 million tonnes of cattle dung equivalent to about 60 million tonnes of fuelwood are burnt annually in our country.
- If this much quantity of cattle dung is incorporated into the soil then it could increase soil productivity.
- Similarly fuelwood is the most significant reason for tree cutting.
- To save forests from degradation, fuel wood tree growing should become part of agriculture through agroforestry in blocks in order to meet out their demands of fuelwood improve the microclimate by means of saving trees in natural forests.
- An energy plantation is one that is grown purely for plant material for their fuel than for fibre content.

Criteria of tree spp. planted for energy plantation

- Tree species should be fast growing with high photosynthetic efficiency which results into high yields.
- Tree species should have high coppicing and pollarding capacity.
- Tree species selected to energy plantation should be conical or cylindrical in shape.
- Tree species should have wood of high calorific value, high wood density, dry weight and burns without sparks or toxic smoke.

- Tree species should be able to tolerate incidences of insects, pests and diseases.
- Tree species should have ability in them to reduce transpiration loss in arid areas.
- Tree species should have ability to fix nitrogen, if possible, that can improve soil fertility without having much competition with main crop for soil moisture, sunlight, etc.
- Tree species should be multiple in nature.

Plate 5.1 *Eucalyplus* Wood Lot

Plate 5.2 *Casuarina equisetifolia* wood lot

SUITABLE SPECIES FOR FIREWOOD/FUELWOOD/ ENERGY PLANTATION FOR DIFFERENT REGIONS

Tropical dry region: *Acacia catechu, Acacia modesta, Acacia nilotica, Acacia Senegal, Acacia tortilis, Anogeissus pendula, Albizia lebbek, Azadirachta indica, Cassia siamea, Cordia rothii, Dalbergia sissoo, Emblica officinalis, Eucalyptus camaldulensis, Erythrina superb, Gmelina arborea, Parkinsonia aculeate, Peltophorum ferrugineum, Pongamia pinnata, Prosopis cineraria, Prosopis juliflora, Tamarindus indica, Tamarix troupe, Tecomella undulate, Zizyphus maurtiana* etc.

Tropical humid region: *Adina cordifolia, Acacia auriculiformis, Acacia catechu, Acacia nilotica, Albizia procera, Azadirachta indica, Cassia siamea, Casuarina equisetifolia, Dalbergia sissoo, Dendrocalamus strictus, Ficus spp., Eucalyptus spp., Kydia calycina, Leucaena leucocephala, Madhuca indica, Melia azedarach, Morus alba, Salix tetrasperma, Syzygium cuminii, Tamarindus indica, Trewia nudiflora, Gliricidia sepium* and *Gmelina arborea.*

Sub-tropical region: *Acacia catechu, Acacia melanoxylon, Acacia nilotica, Aesculus indica, Ailanthus excels, Celtis australis, Grevillea robusta, Michelia champaca, Populus deltoids, Populus nigra, Robinia pseudoacacia, Salix alba* and *Toona ciliate.*

Temperate climate: *Acer spp., Aesculus indica, Alnus nepalensis, Alnus nitida, Celtis australis, Populus ciliate, Quercus semecarpifolia, Salix alba* and *Toona serrata*

- The direct use of firewood in densely populated area should be avoided as it causes environmental pollution.
- Some firewoods on burning give toxic and irritating smoke, and foul odour.
- The firewood may be converted into charcoal which is more efficient.

Charcoal:

- Charcoal is an ideal smokeless fuel for cooking. 1 kg of charcoal has a replacement value of 2.38 kg of firewood or more.
- The combustion efficiency of charcoal is about 28 per cent.
- Thus, conversion of firewood into charcoal for use as a fuel will be better than firewood as such.

- Charcoal is also useful as a reductant in electrometallurgical industries
- Manufacture of calcium carbide, carbon-disulphide and active carbon.
- It does not contain sulphur. The following are a few important trees species for energy plantation: (charcoal making)

Charcoal making: *Acacia nilotica, Adina cordifolia, Anogeissus latifolia, Casuarina equisetifolia, Pinus roxburghi, Quercus leucotrichophora, Quercus semecarpifolia, Tamarindus indica, Terminalia arjuna, Terminalia bellerica, Terminalia chebula* and *Terminalia catappa*

Shrubs for energy plantation: *Atlantia monophylla, Crewia latifolia, Clerodendron inerme, Dodonaea viscose, Jatropha glandulifera, Jatropha curcas, Tecoma gracilis* and *Ipomoea camea* etc.

- Besides firewood and charcoal plants also provide exudates and extractives.
- Such plant species are energy rich and may be exploited as renewable sources of energy.
- These species are known as 'petro-crops', since they can serve as substitutes for supplement to petro chemicals.

Extractive plants: Based on exudates and extractives, plants are classified as those bearing:

i) Latex
ii) Vegetable oil and waxes
iii) Resins
iv) Essential oils
v) Tannins and phenolic compounds bearing plants

Latex yielding plant species:

- Plant species yielding latex belong to Family Apocynaceae, Asclepiadaceae, Euphorbiaceae, Moraceae and Sapotaceae.
- Potential petro-crops are: *Euphorbia antisyphilitica, E. tirucalli, E. lathyris, Pedilanthes tithymaloides, Calotropis procera, Asclepias curassavica* and *Parthenium argentatum*.

Vegetable oils:

- Vegetable oils have great potential to be used as liquid fuel or as a source of hydrocarbons.
- Some of them can be mixed in diesel.
- The non-edible seed bearing oil tree species can be cultivated on poor, marginal and wastelands.
- Important species are
- **Seed-oil bearing plants** *Antinodaphe hookeri, Aleurites triloba, Anacardium occidentale, Aphanamixis polystachya, Azadirachta indica, Calophyllum inophyllum, Cocos nucifera, Croton tiglium, Garcinia indica, Hydnocarpus wightiana, Jatropha curcas, Madhuca indica, Madhuca longifolia, Melia azedarach, Mesua ferrea, Mimusops elengi, Pongamia pinnata, Pittosporum resiniferum, Ricinus communis, Salvadora oleoides, Sapium sebiferum, Schleichera oleosa, Samecarpus anacardium, Shorea robusta, Simmondsia chinesis, Strychnos nux-vomica* and *Vateria indica* etc.

Resins:

- Resins are collected mainly from members of family Pinaceae.
- These are volatile oils (turpentine) and non volatile resins (rosin).
- The resins are main source for synthetic rubber and other polymers.
- Turpines are highly combustible and they can be used in various formulations of fuel for automobiles.

Calorific value:

- The amount of heat produced when 1 g of fuel is completely burnt in excess of air or oxygen.
- If one gram of carbon is burned completely, it produces about 30,000J or 30 KJ/g of heat.
- Therefore, the calorific value of carbon is 30 KJ/g and fuel having high calorific value is regarded as good fuel.
- CV of hydrogen is 150 KJ/g. However, it is not commonly used fuel because of highly combustible nature and difficulty in its handling.

ADVANTAGES OF ENERGY PLANTATIONS

- Emit little or no sulphur and less nitrogen dioxide than fossil fuel
- Helps in rehabilitation of degraded lands
- Provide rural employment
- Alive and active growing forest and other plant biomass absorb the green house gas in quantities broadly equivalent to amount emitted when plant material decay or burned. They are thus called as "Carbon neutral" fuel sources
- Growing energy crops creates a "carbon sink" which includes storing carbon underground through the tree root system
- Lower energy cost per unit area as lower inputs are require as compared to agriculture crops.
- Energy plantations are thought to remove the entire nutrient from soil. However, by use of thermo chemical process of biomass conversion it is feasible to recover all nutrients as ash which can be returned to the plantation sites
- Dependable & renewable source of energy along with afforestation of marginal lands & employment generation.
- Aesthetic value, Windbreak and Shelterbelts.
- Fodder, NTFP etc.
- Handling & disposal of by products is safe.
- Energy plantations are both ecologically as well as sociologically much sounder investments

Table 5.1 A few species used in energy plantations with their respective calorific value and specific gravity

Sr. No.	Species	Sp. gravity	Calorific value K cal/kg
1.	*Acacia auriculiformis*	0.60-0.78	4800-4900
2.	*Acacia catechu*	1.00	5142-5244
3.	*Acacia dealbata*	0.70-0.85	3500-4000
4.	*Acacia leucophloea*	0.78	4899-4886
5.	*Acacia mearnsii*	0.70-0.85	3500-4000
6.	*Acacia nilotica*	0.67-0.68	4800-4950
7.	*Acacia senegal*	-	3200
8.	*Acacia tortilis*	-	4400
9.	*Adina cordifolia*	-	3855
10.	*Aegle marmelos*	0.91	4495
11.	*Albizia lebbek*	0.55-0.64	5163-5166
12.	*Albizia odoratissima*	0.73	5131-5266
13.	*Albizia procera*	0.68	4870-4865
14.	*Alnus nepalensis*	0.32-0.37	4600
15.	*Anogeissus latifolia*	0.94	4948

16.	*Anogeissus pendula*	0.94	4900
17.	*Anthocephalus cadamba*	0.94-0.53	4800
18.	*Artocarpus heterophyllus*	0.51	5318
19.	*Azadirachta indica*	0.75	-
20.	*Baringtonia acutangula*	0.58	5078
21.	*Bauhinia retusa*	0.72	5027
22.	*Bauhinia variegata*	-	4800
23.	*Butea monosperma*	0.54	4909
24.	*Bischofia javanica*	0.74	5162
25.	*Cajanus cajan*	-	4594
26.	*Cassia siamea*	0.60-0.80	-
27.	*Casuarina equisetifolia*	0.80-1.2	4950
28.	*Cedrela toona*	0.57	5113-5168
29.	*Chloroxylon swietenia*	-	4759
30.	*Dalbergia sissoo*	0.75-0.80	4908-5181
31.	*Diospyros melanoxylon*	0.79-0.87	4957-5030
32.	*Diospyros montana*	0.70-0.80	5125
33.	*Dodonaea viscosa*	1.20-1.28	5035-4939
34.	*Emblica offcinalis*	0.70-0.80	5200
35.	*Eucalyptus camaldulensis*	0.6	4800
36.	*Eucalyptus globulus*	0.80-1.00	4800
37.	*Eucalyptus grandis*	0.40-0.70	4900
38.	*Eucalyptus tereticornis*	0.70	4800
39.	*Gmelina arborea*	0.42-0.64	4763-4800
40.	*Grevillea robusta*	0.57	4904-4914
41.	*Grewia spp.*	0.67	5292
42.	*Hardwickia binata*	1.08	4891-4952
43.	*Holoptelia integrifolia*	0.63	5228
44.	*Lannea coromandelica*	0.55	4933
45.	*Leucaena leucocephala*	0.55-0.70	4200-4600
46.	*Madhuca longifolia*	0.56	5043-5156
47.	*Mangifera indica*	0.58	4610
48.	*Melia azedarach*	0.56	5043-5176
49.	*Morus alba*	0.63	4371-4773
50.	*Michelia champaca*	0.45	5068
51.	*Ougeinia oojeinensis*	0.85	5178
52.	*Pithecellobium dulce*	0.64	5177-5600
53.	*Pongamia pinnata*	0.75	4600
54.	*Populus euphratica*	0.48	5008-5019
55.	*Prosopis chilensis*	0.80-0.92	5000-5500

56.	*Prosopis cineraria*	0.77-0.94	5000
57.	*Prosopis juliflora*	0.70	4800
58.	*Pterocarpus marsupium*	0.79	4904-5141
59.	*Pterygota alata*	0.25-0.62	5160
60.	*Quercus leucotrichophora*	0.74	4633
61.	*Schleichera oleosa*	0.91-1.08	4928-4950
62.	*Sesbania grandiflora*	0.55	4407
63.	*Shorea robusta*	0.68-0.82	5095-5433
64.	*Syzygium cuminii*	0.67-0.78	4834
65.	*Tamarindus indica*	0.91-1.28	4909-4969
66.	*Tamarix aphylla*	0.60-0.75	4835
67.	*Tectona grandis*	0.55-0.70	4989-5535
68.	*Terminalia alata*	0.71-0.94	5047-5373
69.	*Terminalia arjuna*	0.74-0.82	5030-5128
70.	*Terminalia chebula*	0.77	3967
71.	*Trema orientalis*	0.48	3095
72.	*Xylia xylocarpa*	0.92	4975-5044
73.	*Zizyphus mauritiana*	0.93	4900

LECTURE-6

LEARNING OBJECTIVE: TO KNOW ABOUT PLANNING FOR AGROFORESTRY – CONSTRAINTS, DIAGNOSIS & DESIGN METHODOLOGY

AGROFORESTRY PLANNING OF FARMS

- Agroforestry is the management of interactions between trees, crops and livestock in each of the farms plots, aiming to reach the objectives set by the farmer or the family
- Interactions are the effects of one component over another component
- Interactions are always not positive it may negative and compete for the different resources For example. Dense canopy trees in cropped areas create a shade to the underground crop and thus the interaction may fall on negative side
- The manager must take advantages of positive interactions and eliminate or reduce negative interactions
- The agroforestry planning of farms allows manager to manage interaction in order to maximize production, value and conservation
- The agroforestry planning of farms is applicable to farms of all sizes

- Researchers in developing countries are trying to reach out to farmers through on-farm experimentation.
- The partnership is still somewhat one sided.
- Scientist go out to the farmers and bring back information to help them
- Decide how best to make their technologies more relevant to their client's needs.
- What is needed is a communication channel in which information about technology and research needs and priorities flows with equal ease in both directions.
- The farmer or other land user makes the final decision on whether or not to adopt an agroforestry technology for use in a particular land use system.
- In order to help agroforestry researchers, ICRAF's team of anthropologists, economists, agricultural and forestry researchers - together with participating men and women farmers have developed a methodology for the diagnosis of land management problems and the design of agroforestry solutions.

- This is simply a systematic approach for applying to agroforestry the common sense medical principle that 'diagnosis should precede treatment'.

CONSTRAINTS OF AGROFORESTRY

- The interference of trees decreases the crop yield which is lower than the monocropping
- The tree canopy absorbs maximum light and causes competition for light
- Felling of trees causes damage to the arable crop
- Competition for moisture between trees and arable crops is maximum when the trees have not deep tap root system
- Some of the trees serves as host to pest that harm main crop
- Agroforestry system requires more for its management
- Longer gestation period for tree delay the returns to the farmer
- Farmers give more weightage to field crops compare to tree crop
- Certain tree species produce chemical exudation which affects the growth of agriculture crops

THE GENESIS OF D&D

- Agroforestry in itself is described as 'a new name for an old practice'.
- The D&D methodology is an adaptation of old or existing methodologies to the specific needs and conditions of agroforestry.
- Several methodologies have been developed for holistic evaluation and analysis of land use systems. The most significant among these are:

i) Farming Systems Research /Extension (FSR/E)
ii) Land Evaluation methodology

- Each of these two was developed with specific objectives and conditions. For example, the FSR/E was developed in response to the failures or inadequacies of the traditional transfer-of-technology extension methods that were initiated to disseminate the researcher-driven green revolution technologies to resource-poor, small scale farmers.
- FSR/E was designed to be interdisciplinary and holistic as well as demanding farmer involvement from the outset The D&D arose, in the words of J.B. Raintree, who directed

its development at ICRAF, "Out of the demands of the agroforestry situation. It gives a special focus on agroforestry related constraints and opportunities within existing land use systems and highlights agroforestry potentials that might be overlooked by other methodologies. For example, for most FSR/E practitioners, the trees within the farming system tend to be invisible".

WHAT IS D&D?

DIAGNOSIS AND DESIGN

D&D is a methodology for the diagnosis of land management problems and design of agroforestry solutions. It was developed by ICRAF to assist agroforestry researchers and development fieldworkers to plan and implement effective research and development projects.

THE KEY FEATURES OF THE D&D:

A. FLEXIBILITY

D&D is a flexible discovery procedure which can be adapted to fit the needs and resources of different users.

B. SPEED

D&D has been designed with the option of a 'rapid appraisal' application at the planning stage of a project with in-depth follow up during project implementation.

C. REPETITION

D&D is an open-ended learning process. Since initial designs can almost always be improved, the D&D process need not end until further improvements are no longer necessary.

CRITERIA OF A GOOD AGROFORESTRY DESIGN

There is no substitute for good design. A good agroforestry design should fulfill the following criteria:

A. PRODUCTIVITY

There are many different ways to improve productivity with agroforestry: increased output of tree products, improved yields of associated crops, reduction of cropping system inputs, increased labour efficiency, diversification of production, satisfaction of basic needs, and

other measures of economic efficiency or achievement of biological potential.

B. SUSTAINABILITY

By seeking improvements in the sustainability of production systems, agroforestry can achieve its conservation goals while appealing directly to the motivations of low income farmers, who may not always be interested in conservation for its own sake.

C. ADAPTABILITY

No matter how technically elegant or environmentally sound an agroforestry design may be, nothing practical is achieved unless it is adapted by its intended users. This means that the technology has to fit the social as well as the environmental characteristics of the land use system for which it is designed.

WHO CAN MAKE USE OF D&D?

- Researchers
- Extension officer
- Government field workers
- NGOs

BASIC PROCEDURE OF D&D

The basic logic of the D&D discovery procedure is displayed in the following table 1. The process can be subdivided into small steps and used selectively for varying purposes, but the hierarchical logic of D&D is quite robust and generally applicable to virtually any problem in technology design. The more detailed procedural suggestions are best thought of optional steps for collecting and processing the information needed to answer the basic question shown in the table 1. At any time you feel you are getting lost in the details, simply return to this outline of basic procedures for a reorientation to know where you are in the process.

Table 6.1 Basic procedure of D&D

D&D Stages	Basic Questions to answer	Key factors to consider	Mode of inquiry
Prediagnostic	Definition of the land use systems and site selection (which system to focus on?)	Distinctive combinations of resources, technology and land user objectives	Seeing and comparing The different land use systems

	How does the system work? (How is it organized, how does it function to achieve its objectives?)	Production objectives and strategies, arrangement of components	Analyzing and describing the system
Diagnostic	How well does the system work? (What are its problems, limiting constraints, problem-generating syndromes & intervention points?)	Problems in meeting system Objectives (production short-falls, sustainability problems Casual factors, constraints and interventions points	Diagnostic interviews and direct field observations Troubleshooting the problems, subsystems
Design & Evaluation	How to improve the system? (What is needed to improve system performance?)	Specifications for problem solving or performance enhancing interventions	Iterative design and evaluation of alternatives
Planning	What to do to develop and disseminate the improved system?	Research and development needs, extension needs	Research design project planning
Implementation	How to adjust to new information?	Feedback from on-station research, on-farm trials and special studies	Re-diagnosis and re-design in the light of new information

D&D IS AN ITERATIVE PROCESS

The basic D&D process is repeated throughout the project implementation stage to refine the original diagnosis and improve the technology design in the light of new information from on-farm research trials, more rigidly controlled on-station investigations, and eventual extension trials in a wider range of sites. As shown in the following flowchart, the iterative D&D process provides a basis for close feedback complementarily between different project components. By adjusting the plan of action to new information, the D&D process becomes self corrective. In an integrated agroforestry research and extension programme, the pivotal decisions are taken in periodic meetings which evaluate new results and revise the action plan accordingly. The process continues until the design is well optimized and further refinement is deemed unnecessary. You can enter the cycle at any point, but the ultimate fine-tuning and dissemination of the technology will most likely be accomplished by the farmers themselves.

KEY CONCEPTS OF D&D

a) D&D is system specific

b) Definition of the system for D&D purposes

A land use system is defined as a distinctive combination of three interrelated factors: the land resources, exploited by a particular technology, to satisfy the production objectives of a particular type of land user.

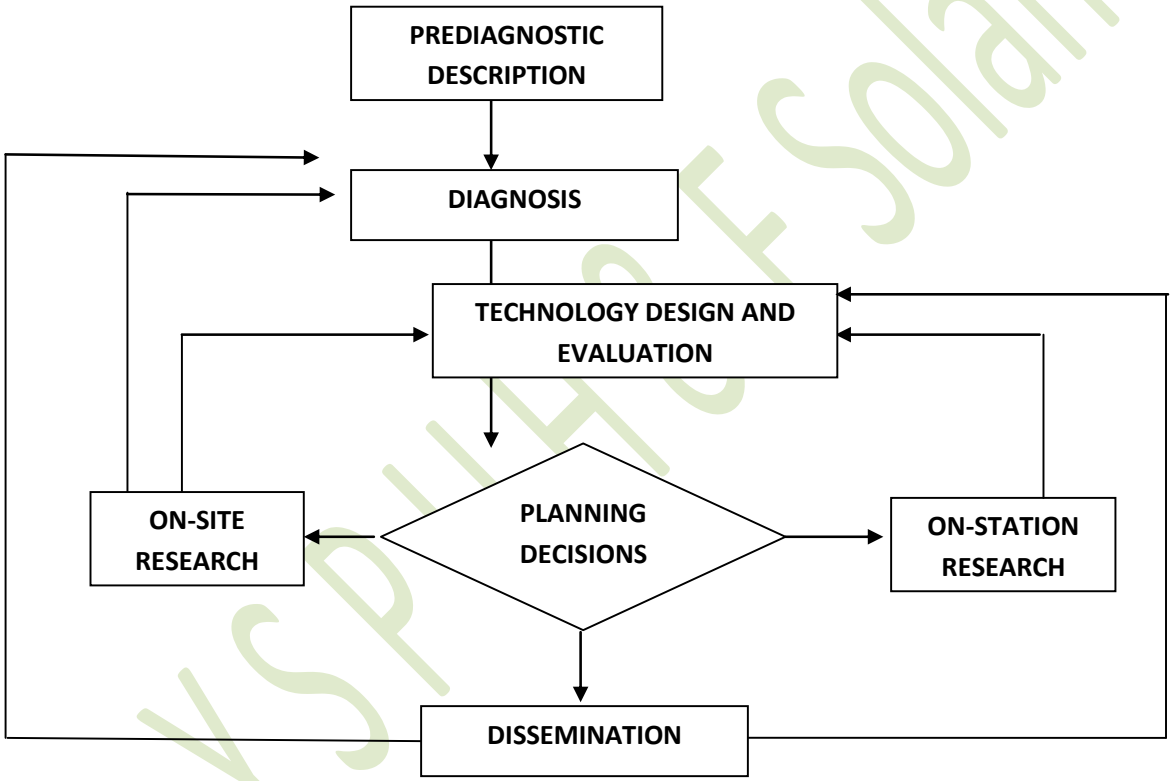

Fig. 6.1 D&D IS AN ITERATIVE PROCESS

C) The diagnosis leads to 'specifications' for interventions

The end product of diagnostic procedure is a set of functional specifications:

- What the system needs
- How these needs can best be satisfied

D) Specifications suggest 'candidate technologies'

E) 'Technology specifications' complete the design

- The actual choice of component species

- Spatial arrangement
- Management practice, etc.

F) The design reveals research needs and extension opportunities

G) If at first you do not succeed, try and try and try again

LECTURE -7

LEARNING OBJECTIVE: PLANNING FOR AGROFORESTRY-CONSTRAINTS, DIAGNOSIS & DESIGN METHODOLOGY (contd…)

I. BASIC PRINCIPLES AND PROCEDURES

Step 1. Planning of study

- Identify objectives
- Specify area to be covered
- Identify collaborating institutions and staff
- Select and adapt D&D methods to be used

Step 2. Regional Reconnaissance

- Identify, map and describe major land units and population distribution

Step 3. Identification and preliminary description of land use system

- Differentiate and describe important land use systems
- Make a preliminary assessment of their constraints and problems
- Make a preliminary assessment of their agroforestry potential

Step 4. Site selection

- Select land use systems for priority attention based on:

i) Severity of problems
ii) Agroforestry potential
iii) Regional representativeness

- Select sites representative of the chosen systems for in depth D&D

II. DIAGNOSTIC STAGE

Step 5. Diagnostic survey

- Conduct field survey of representative management units to identify common land use strategies and problems
- Troubleshoot the production systems to identify causal factors and constraints
- Investigate interactions between and within management units and processes in the

general landscape

Step 6. Diagnostic analysis

- Analyze field data to identify key constraints and intervention points for development of system potential
- Assess sustainability problems

Step 7. Specifications for appropriate interventions

- List system specifications

i) Functional specification for interventions
ii) Design constraints
iii) Desirable attributes of new technology
iv) Overall development strategy for the system

III. TECHNOLOGY DESIGN STAGE

Step 8. Identification of candidate technologies

- List feasible technologies which meet the system specifications
- Select and prioritize the most promising technologies and combinations

Step 9. Detailed technology specifications

- Make a detailed list of desirable attributes of each of the selected technologies (component characteristics, management. considerations, etc.)
- Prioritize the attributes on this list in the light of the total knowledge of the diagnosed system

Step 10. Technology design

For each specific technology, give detailed answers to each of the following questions:

i) What functions should each intervention address?
ii) At what location within the farm or general landscape should these functions be performed?
iii) What component or combination of components (plant/animal species and varieties) are the best choices for performing these functions?

iv) How many of each component are required to meet production targets?

v) What precise arrangement of components is envisaged?

vi) What management practices are required to achieve the desired performance characteristics?

Take note of all design questions to which the D&D team is presently unable to give satisfactory answers (these are topics for further consultation or research).

Synthesize all of the above into an integrated design for an agroforestry system which best answers the needs and potentials of the existing land use system (consider stepwise introduction of component technologies if the full system is likely to be too much for local farmers to adopt all at once).

IV. EVALUATION AND REDESIGN STAGE

Step 11. Ex-ante evaluation and redesign

- Check land user's response to the design proposal (optional D&D verification survey)
- Conduct a preliminary evaluation of the agroforestry design, compare with present land use and non-agroforestry alternatives in terms of:

i) Productivity (biological potential, economic efficiency and diversity of production

ii) Sustainability (Environment impact, resource conservation)

iii) Adoptability (fulfillment of felt needs, cultural comparability, social distribution of benefits)

- Return to design stage activities to make modifications suggested by the preliminary evaluation

Step 12. Suitability classification

- Summarize system evaluations for each of the design agroforestry systems and develop classification of suitability for wider application
- Combine this classification into suitability maps and tables for the study area/region as a whole (define preliminary recommendation domain)

V. PLANNING STAGE

Step 13. State of knowledge review and assessment of research needs

- Assess readiness of each of the designed technologies for direct extension and/or need for further research
- Compile integrated list of research needs, including:

i) Need for further D&D (pre-project follow up and/or monitoring of field trials during project implementation
ii) On-farm trials of candidate technologies

- Farmer managed trials to assess adoptability and elicit farmer's own design ideas
- Researcher managed trials to evaluate experimental variables under:

i) On-station investigations under controlled conditions to obtain detailed information on component interactions, response to management, germplasm screening, etc.

Step 14. Research and extension plan

- Develop overall plan of action, detailing:

i) Individual research investigations
ii) Extension activities
iii) Integration of research and extension goals and activities
iv) Collaboration in research and extension networks

VI. IMPLEMENTATION STAGE

Step 15. Implementation of R&D and extension activities

- Continue to apply the iterative D&D process to refine prototype agroforestry systems on the basis of feedback from research and extension experience (re-diagnosis and re-design)
- Institutionalize communication channels between different programme components (hold periodic meetings to pool experience, assess new developments and modify the plan of action in the light of new experience)

Comparison of D&D with similar methodologies

Several methodologies that endeavour to design improved and appropriate land-use systems are currently in use, and at least two of them, the FSR/E and Land Evaluation, have been in use for the longer period than the D&D. Comparisons have been made between D&D and these other longer-established methods . With regard to procedural aspects, D&D is more closely related to the FSR/E (sometimes D&D is even portrayed as a form of FSR/E). According to Raintree, D&D is, however, different from FSR/E in the following aspects:

- It possesses a broader diagnostic scope, giving specific attention to the role of trees within the farming system;
- It has a more elaborate technology design step, which is needed to visualize the more complex landscape intervention typical of agroforestry;
- It may be applied at variable-scales; and
- It places a greater emphasis on the iterative nature of a diagnostic and design process.

A detailed comparison of D&D with Land Evaluation has been made by Young. He argues that if Land Evaluation is applied to agroforestry, then the wrong methodologies are attempting to accomplish virtually the same task: to find out the best system of improved land use for a given site. One of the main differences, however, appears to be a stronger treatment of environmental aspects in Land Evaluation, and a stronger treatment of social aspects in D&D.

Another relatively new methodology of similar nature is the agro-ecosystem analysis. This is a conceptually simpler methodology for rapid rural appraisals. Although no systematic comparison has been made between D&D and agro-ecosystems analysis, the two approaches share the same philosophy. Another recent holistic approach to land management that has originated from the rangeland management perspective places a greater emphasis on design as opposed to diagnosis.

It will thus appear that all these methodologies have the same essential features; each, however, has specific merits for specific situations. The D&D because of its agroforestry orientation is more popular in agroforestry circles. Nonetheless, if agroforestry itself is considered as a subset of farming systems (as Farming Systems experts sometimes claim) and FSR/E becomes broader and visualizes tree on farms as essential components of farming

systems, the remaining differences, if any, between FSR/E and D&D will be of purely academic interest.

But the fact remains that these are only methodologies for logically addressing land-use problems; they are not substitutes for action, i.e., testing, refining, and disseminating interventions. Additionally, a sound grasp of biological and social problems, as well as knowledge of possible interventions and a creative approach, are required of the multidisciplinary teams. The suitability of the diagnosis and the design will be a function of their knowledge and creativity; similarly, the success of the action depends on the merits of the available technologies. Furthermore, the methodologies can, at best, only identify the problems and suggest the solutions; the solutions themselves depend on how the knowledge is advanced and applied.

LECTURE - 8

LEARNING OBJECTIVE: TO KNOW ABOUT SELECTION OF TREE CROP SPECIES FOR AGROFRESTRY

Agroforestry is a deliberate integration of trees and crops in general, in same unit of land. These trees and crops compete with each other for nutrients, moisture and light. Therefore there are both +ve and –ve interaction among different components. In order to have a positive interaction among different components one must select a compatible component so that from a single unit of land a farmer/cultivator maximize his production. While selecting tree species for agroforestry three factors must taken into consideration such as...

- **CLIMATE**
- **SOIL**
- **BIOTIC FACTOR**

CLIMATE:- TREE SPECIES SELECTED FOR AGROFORESTRY TAKEN INTO ACCOUNT CLIMATE FACTOR

Hot desert: *Prosopis cineraria, P. chinensis, Acacia tortilis, Capparis spp, Tecomella undulate*

Cold desert: *Populus nigra, P. cilita, P. alba, P. tremula, P. euphretica, salix alba, S fragilis, Juniperus*

Tropical semi-arid: *Prosopis spp, Acacia tortilis, A. nilotica, A. senegal, Albizia lebbeck, Eucalyptus camaldulensis, Azadirachta indica, Salvadora persica, Tamarix spp*
Subtropical semi arid: *Pinus roxburghii, Acacia modesta, Albizia procera, Bauhinia variegata, Morus indica, Ficus spp*

Temperate semi arid: *Pinus gerardiana, Juniperus macropoda, Corylus colurna*

Humid tropical: *Terminalia myriocarpa, Tectona grandis, Terminalia alata, Schima wallichi, Gmelina arborea, Dipterocarpus macrocarpus, Cocus nucifera, areca catechu, Artocarpus*

heterophyllus, Pterocarpus santalinus, Chukrasia tubularis

Humid subtropical: *Eucalyptus globulus, Acer oblungum, Acrocarpus fraxinifolius, Aesculus indica, Pinus kesiya, Prunus spp, Quercus spp*

Humid temperate: *Acer campbelii, abies pindrow, Quercus spp, Robinia pseudacacia, Pinus alata, P. wallichiana, Alnus nitida, Populus ciliata, Cryptomeria japonica*

Subtropical semi-humid: *Albizia chinensis, Pinus roxburghii, P. kesiya, P. ellioti, Grewia optiva, Celtis australis, Eucalyptus grandis, E. globulus, Toona ciliate*

Tropical sub-humid: *Eucalyptus teriticornis, E. citridora, Casuarina equisetifolia, Dalbergia latifolia, Bombax ceiba, Morus alba, Leucaena leucocephala, Dalbergia sissoo, Anthocephalus chinensis, Adina cardifolia, populus deltoides, Moringa oleifera*

Subtropical semi-humid: *Albizia chinensis, Pinus roxburghii, Grewia optiva, Celtis australis, Morus indica, Toona ciliata, Eucalyptus grandis, Eucalyptus globules*

Temperate semi-humid: *Acacia mearnsii, Acer oblungum, Alnus nepalensis, Cedrus deodara, Celtis australis, Fraxinus spp, Quercus spp, Juglans regia*

SOIL:- TREE SPECIES SELECTED FOR AGROFORESTRY TAKING INTO ACCOUNT SOIL TYPE

Desert soil: *Prosopis cineraria, P. chilensis, Acacia tortilis, A. senegal, A. nilotica, Salvadora spp*

Recent alluvium: *Acacia catechu, Dalbergia sissoo, Bombax ceiba* etc.

Old alluvium:

Saline-alkali soils: *Prosopis spp, Acacia nilotica, Azadirachta indica, Ailanthus spp, Eucalyptus spp, Tamarix spp, Pongamia pinnata*

Coastal and deltaic alluvium: *Casuarina equisetifolia, Cocus nucifera, Areca catechu, Avicennia spp*

Red soils: *Tectona grandis, Madhuca indica, Mangifera indica, Dalbergia sissoo, Acacia nilotica, Leucaena leucocephala, Azadirachta indica, Eucalyptus hybrid, Pterocarpus marsupium, Adina cardifolia, Dendrocalamus strictus*

Black cotton soils: *Acacia nilotica, A leucophloea, Tectona grandis, Hardwickia binnata, Adina cardifolia, Tamarandius indica, Aegle marmelos, Bauhinia spp, Dalbergia latifolia*

Laterite and lateric soils: *Tectona grndis, Eucalyptus spp, Acacia auriculiformis, Azadirachta indica, Tamarindus indica, Emblica officinalis*

Peaty and organic soil: *Syzygium cuminii, Ficus glomerata, Bischofia javanica, Lagerstromia speciosa, Glircidia sepium*

Hill soils: *Juglans regia, Alnus nitida, Toona serrata, Cedrus deodra, Quercus spp, Grewia optiva, Celtis australis*

BIOTIC FACTORS:- Choice of species is also governed by biotic factors such as grazing, fire and incidence of Insect pest etc.

DESIRABLE CHARACTERISTICS FOR AGROFORESTRY

While selecting tree species for agroforestry systems, the following desirable characteristics should be taken into consideration. Though all desirable characters are not found in a single species, but their multiple uses are taken care of.

- **Tree species selected should not interfere with soil moisture**

  - ✓ Tree species selected for agroforestry should have very less water requirement
  - ✓ Should not compete with main agricultural crops for water.
  - ✓ Tree species should be deep tap rooted so that they can draw water from deep strata of the soil.

- **Tree species should not compete for plant nutrients**

  - ✓ Tree species should not utilize more plant nutrients
  - ✓ They should help in building soil fertility,
  - ✓ Leguminous tree species which fix atmospheric nitrogen in their roots should be prfer.
  - ✓ The root system and root growth characteristics should ideally result in to exploration of soil layers that are different to those being trapped by agricultural crops.

- **Tree species should not compete for sunlight**

- ✓ Tree species should not interrupt sunlight falling on the crops.
- ✓ Tree species should be light branching in their habit.
- ✓ Trees permit the penetration of light into the ground and promote better crop, pasture growth and yield.
- ✓ Tree species can withstand pruning operation if it posses dense canopy.

- **Tree species should have high survival rate and easy establishment**
  - ✓ Trees species should have high survival percentage,
  - ✓ Leave little or no gaps after transplanting.
  - ✓ Hardy tree species are easy to establish.
  - ✓ They have less mortality percentage because they can tolerate transplanting shocks easily.
  - ✓ Trees should have the ability to regenerate lateral roots within a short period of time after transplanting.

- **Tree species should have fast growing habit and easy management**
  - ✓ Tree species for agroforestry system should be essentially fast growing,
  - ✓ Rapid growth, especially in the early years,
  - ✓ Tree should have short rotation (the period between planting and final harvesting)
  - ✓ Fast growing species such as Poplar, *Casuriana*, *Leucaena leucocephala* etc. are important species which provide lot of opportunities to be planted in AFS

- **Tree species should have wider adaptability**
  - ✓ A tree species selected for agroforestry combinations must have a wider adaptability.

- **Tree species should have high palatability as a fodder**
  - ✓ Most of the Indian farmers rear livestock separately and cut and carry method of fodder production is quite prevalent.
  - ✓ Therefore, in agroforestry, farmer must select those tree species which are palatable to livestock and had a high digestibility.

- **Tree species should have shelter conferring and soil stabilization attributes**
  - ✓ Some tree species, because of their inherent growth habit and adaptability, are especially

helpful in providing protection for soils, crops and livestock. Poplars (*Populus* spp.), Willows (*Salix* spp.), *Casurina equisetifolia,* etc. for example, have been extensively used in soil erosion control because of their extensive root system and ability to grow in water-logged soils.

- **Tree species should have capability to withstand management practices**
  - ✓ Many agroforestry systems demand extensive pruning and lopping of the trees in order to maximize production. In such cases, the trees must be able to withstand such treatment without drastically restricting growth rate.
- **Tree species should have nutrient cycling and nitrogen fixation attributes**
  - ✓ Within an agroforestry system, trees can play an important role in recycling nutrients, leached down through the soil profile and minerals released from weathering parent material such as rocks and sediments.
  - ✓ These nutrients are used in the growth and development of the tree, many returning to the top-soil in form of dead leaves, twigs, flowers and seeds which slowly decompose on the surface, or are eaten by animals.
  - ✓ Although all trees play some role in maintaining the nutrient status of the soil through recycling.
  - ✓ Deciduous trees drop most of their leaves in autumn leaving a thick mat of leaves on the ground, whereas most evergreen species maintain some level of litter fall throughout the year.
  - ✓ Another important factor is the ability of many tree species to convert atmospheric nitrogen into organic nitrogen for their own use through complex symbiotic relationship between Rhizobium bacteria and their fine roots.
  - ✓ The bacteria form nodules on the roots which can convert nitrogen gas, as it is in the atmosphere, into usable nitrogen for the plant.
  - ✓ Most leguminous trees and some non-leguminous ones, such as *Acacia*, *Leucaena* and *Prosopis* as well as *Casuarina* spp. fix the atmospheric nitrogen.
  - ✓ The litter of these nitrogen fixing trees is generally high in nitrogen, thus increasing the nitrogen status of the soil.

The following are a few tree species which help in fixing atmospheric nitrogen through their roots:

Table 8.1 Nitrogen fixing tree species

1.	*Acacia albida*	21.	*Bauhinia variegata*
2.	*Acacia auriculiformis*	22.	*Butea monosperma*
3.	*Acacia catechu*	23.	*Cassia fistula*
4.	*Acacia aneura*	24.	*Cassia siamea*
5.	*Acacia dealbata*	25.	*Casuarina equisetifolia*
6.	*Acacia decurrens*	26.	*Dalbergia latifolia*
7.	*Acacia farnesiana*	27.	*Dalbergia sissoo*
8.	*Acacia implexa*	28.	*Delonix regia*
9.	*Acacia leucophloea*	29.	*Gliricidia sepium*
10.	*Acacia mearnsii*	30.	*Hardwickia binata*
11.	*Acacia melanoxylon*	31.	*Leucaena leucocephala*
12.	*Acacia mollissima*	32.	*Moringa oleifera*
13.	*Acacia nilotica*	33.	*Oogeinia oojeinensis*
14.	*Acacia planifrons*	34.	*Parkinsonia aculeata*
15.	*Acacia senegal*	35.	*Peltophorum ferrugineum*
16.	*Albizia chinensis*	36.	*Pithecellobium dulce*
17.	*Albizia lebbek*	37.	*Prosopis alba*
18.	*Albizia procera*	38.	*Prosopis chilensis*
19.	*Alnus nepalensis*	39.	*Prosopis cineraria*
20.	*Alnus nitida*	40.	*Robinia pseudoacacia*
41.	*Samanea saman*	44.	*Sesbania bispinosa*
42.	*Saraca indica*	45.	*Sesbania grandiflora*
43.	*Sesbania aegyptica*	46.	*Tamarindus indica*

- **Tree species should have thin bark**
  - ✓ Species selected for agroforestry combinations should not shed its bark regularly but it should retain for longer period as bark shedding creates unhygienic conditions for under-ground crop.

- **Tree species should be free from chemical exudations**
  - ✓ The species selected for agroforestry combination must be free from allelo-chemicals as these allelo-chemicals affect the growth of under-ground crops.

- **Tree species should have easily decomposable leaves**
  - ✓ The suitable tree species for agroforestry will be that one in which fallen leaves decompose with fast rate.

- ✓ The leaves of most of the legume tree species are small in size, decompose quickly and easily, and add a large quantity of organic matter and nutrients to the soil.
- ✓ Tree species having broad leaves such as teak, mango and banyan should not be preferred for agroforestry system.
- ✓ They contain more fibre matter and also require longer time for decomposition. Further, broad leaves when fall on the tender crop plants, block their photosynthetic activities.

- **Tree species should have their multiple uses**

  - ✓ The selected tree species should have multiple uses.
  - ✓ The tree should yield more than one of the main produce like fuelwood, leaf fodder, edible fruit, edible flower and fibre.

- **Tree species should have high yield potential**

  - ✓ High yield potential is the most important criterion of selection of tree species for agroforestry systems as the main aim is to obtain overall more output per unit area. Care should be taken before collection of seeds and seedlings that they are being procured from reliable source.

CHARACTERISTICS OF AGRICULTURAL CROPS FOR AGROFORESTRY

a) Agricultural crops should be short duration and quick growing.
b) They should be at least partially tolerant to shade.
c) Most of them should belong to Leguminosae family.
d) They should respond well to high density tree planting.
e) They should bear some adverse conditions, like water stress and/or excess of watering;
f) Crops should return adequate organic matter to soil through their fallen leaves, root system, stumps, etc.
g) Crops should appropriately be fitted in intensive or multiple cropping system.

LECTURE - 9

LEARNING OBJECTIVE: TO KNOW ABOUT DIFFERENT NATIONAL AND INTERNATIONAL INSTITUTES WORKING IN THE FIELD OF AGROFORESTRY/FORESTY

IDRC Canada (1975), commissioned John Bene to undertake the study to:

- Identify significant gaps in world forestry research and training
- Assess the interdependence of forestry and agriculture in low income tropical countries and propose research leading to optimization of land use
- Formulate forestry research programs which promise to yield results of considerable economic and social impact on developing countries
- Recommend institutional arrangements to carry out such research effectively and expeditiously
- Prepare a plan of action to obtain international donor support

Bene concluded that

- First priority should be given to the combined production system which would integrate forestry, agriculture, and/or animal in order to optimize the land use
- Research project carried earlier were unplanned and haphazard
- Need for establishment of international organization which would support, plan, and coordinate, on a world-wide basis, research combining the agriculture and forestry
- The systematic research in agroforestry geared up after establishment of International Council for Research in Agroforestry (ICRAF) in 1977 and the ancient practice of AF was instutionalized for the first time.
- Renamed as The International Centre for Research in AF (ICRAF) in 1991
- Now known as World Agroforestry Centre (WAC)

INDIA

- IGFRI, CSWCRTI, CRIDA, CAZRI, ICAR complex for NE region started agroforestry research in 1960-70s
- In seventh five year plan (1985-90) NCA emphasis importance of AF and it was introduced to agriculture syllabus at that time.

- Organised research in agroforestry was initiated during VI plan period in 1983 with start of All India Coordinated Research Project for Agroforestry (AICRP(AF)) project at 20 centres (State centres at Agricultural Universities- 12 and ICAR Research Institutes-8).
- Recognizing importance NRCAF was proposed in seventh five year plan
- In VII plan 11 more centres at SAUs were added in the project.
- After inclusion of 2 new centres at TNVASU, Kattupakkam and IGKV, Raipur during the VIIIth plan total 33 regular centres are working besides 5 voluntary centres.
- The total number of centres engaged in agroforestry coordinated project is 39 (33 regular, 5 voluntary and I PC unit).

INTERNATIONAL INSTITUTES WORKING IN THE AREAS OF FOREST CONSERVATION AND RESEARCH

1) **Food and Agriculture Organization (FAO)**

- The headquarters is in Rome (Italy)
- It plays an important role in coordinating and implementing forestry genetic resources policy within its overall aim of providing technical assistance.
- Emphasis is paid, in technical terms, on the use of multipurpose species. The species in the arid and semi-arid regions of developing countries are given priority as they are subjected to high human and biotic stress.
- Efforts are done to explore, use and conserve gene resources of forest trees. In this regard increased attention has been paid to *in situ* conservation as a desirable complement to various forms of *ex situ* conservation.
- It disseminates the information on forest tree seed supplies, seed collection, handling, storage, testing and certification. The organization and results of international provenance trials and various aspects of the conservation and use of genetic resources, through a newsletter, Forest Genetic Resources Information.

2) **The International Board for Plant Genetic Resources (IBPGR**)

- The headquarters is in Rome (Italy).
- It is an international scientific centre of the Consultative Group on International Agriculture Research (CGIAR).
- It is working on agricultural crops, forest species, particularly fuel wood species, for their conservation and improvement.

3) **International Council for Research in Agroforestry (ICRAF)**

- Established in 1977. Its headquarters is in Nairobi, Kenya.
- Established as an international scientific centre devoted to improving the nutritional, economic and social well-being of people in developing countries by promoting agroforestry system for enhanced use of the land without degrading the environment.
- It acts as a catalyst for agroforestry research, training and information dissemination.

4) **International Tropical Timber Organization (ITTO)**

- Its headquarters is in Yokohama, Japan.
- The purpose of ITTO is to provide an effective frame work for cooperation and consultation between tropical timber producing and consuming countries regarding all aspects of the tropical timber economy.
- Its major activity related to forest genetic resources involves funding of projects directed at the conservation and sustainable use of tropical forests.

5) **International Union for the Conservation of Nature and Natural Resources (IUCN)**

- Its headquarters is in Gland, Switzerland.
- It is a unique international agency as it is constituted with both governmental and non-governmental membership.
- It is concerned with species level conservation and has paid increasing attention to plant genetic resources.
- It produces the IUCN plant Red data book, a series that gives detailed case histories on rare and threatened plants in all parts of the world; for each species, data are given on conservation status, threats to survival, distribution and habit, together with a short description and an evaluation of its interest or potential value to humankind.
- It has a World Conservation Monitoring Center (WCMC) located at Cambridge, UK for data storage and processing and also provides information on international trade in endangered plants and animals.

6) **International Union of Forestry Research Organization (IUFRO**)

- Its headquarters is situated in Vienna, Austria.

- It coordinates and assists scientists participating in programmes. It has placed strong emphasis on industrial species and works on provenance testing, progeny testing and breeding of specific species. It is also working on conservation and on population genetics for the species of temperate zone and Mediterranean conifers, as well as *Quercus* spp., *Eucalyptus* spp., *Populus* spp.

7) **United Nations Environment Programme**

- Its headquarters is in Nairobi, Kenya.
- It is an agency of United Nations.
- It works with various governments, other UN organizations and non-govt. organizations around the globe to monitor the state of global environment. Much of the UNEP's work is aimed at promoting public awareness of the importance of genetic diversity and methods of conserving and managing that diversity for the future.

8) **United Nations Educational, Scientific and Cultural Organization (UNESCO)**

- Its headquarters is in Paris, France.
- UNESCO's involvement in gene conservation is primarily through its MAB Programme (Man and Biosphere Programme)
- The objectives of MAB are to establish project areas based on ecosystem concept (including human activity) to conserving representative ecosystems with zoned management to developing biosphere reserves that conserve biological diversity and its genetic resources.

9) **Consultative Group on International Agriculture Research (CGIAR).**

- Its secretariat is located in Washington DC, USA.
- It was established to help coordinate the efforts of developed and developing countries, public and private institutes and international and regional organizations to support a network of 13 international agricultural research centers.

NATIONAL AND REGIONAL INSTITUTIONS

This section describes selected national and regional institutions with international programmes bearing on forest genetic resources.

1) Central America and Mexico Coniferous Research Cooperative (CAMCORE)

- The private organizations have been able to directly effect the development of genetic resources by the cooperative efforts.
- It has sponsored collection for some 30 Central American and Mexican conifer and angiosperm species. From the collections, seeds are processed, stored and distributed to cooperating agencies for establishing conservation stands and provenance and progeny tests.
- Main aim is to prevent reduction & loss of germplasm.

2) Centre Agronomics Tropical De Investigation Ensenanza (CATIE)

- The member countries are Central American and Latin American ones like Costa Rica, Dominican Republic, Guatemala, Honduras, Nicaragua and Panama.
- Working for the renewal of natural resources by the renewable natural resources development which has four programmes: agroforestry, silviculture, wild lands and watershed management. It also works on *ex-situ* conservation.

3) Canadian International Development Agency and International Development Research Centre

- Headquarters in Canada.
- It finances various projects which work for forestry research in developing countries.

4) Centre Technique Forestier Tropical (CTFT)

- It is a department of French foreign assistance agency.
- It works for 12 francophone sub-Saharan African countries and French Guiana and New Caledonia.
- It also works for selected species like: *Eucalyptus* spp, *Pinus caribaea*, *Pinus kesiya*, *Terminalia superba*, *T. ivorens*, *Tectona grandis*, *Gmelina arborea*, *Cedrela odorata*, *Cordia alliodora*, *Acacia mangium*, *A. auriculiformis*, *A. albida* and *A. senegal*. It works for these species in all aspects - silviculture, breeding, conversion and utilization, and *ex-situ* conservation.

5) Commonwealth Scientific and Industries Research Organization (CSIRO)

- Headquarters in Canberra, Australia.

- Key programmer on Australian forest tree resources is Tree Seed Centre, where the centre collects and distributes high quality and source identified seeds of commercially promising Australian woody plants for research purposes, provides professional advice on the choice of species and seed supply, and provides technical information on species of value.

6) Danish Forest Seed Centre (DFSC)

- Headquarters in Humleback, Denmark.
- Most of the activities are taking place in developing countries, primarily in South-East Asia and Central America.
- Major activity is in handling, storage and distribution of seed collected within FAO/IBPGR/UNEP projects on genetic resources of arid and semi-arid zone arboreal species for improvement of rural living.

7) Oxford Forestry Institute (OFI)

- Based in United Kingdom
- Formerly it was known as 'Commonwealth Forestry Institute'.
- It is a world centre for research and development. It is working for the establishment of international provenance testing projects for some 50 species in Central America and parts of Africa. The project covers - exploration, taxonomy, collection, seed storage, distribution, conservation and development of genetic improvement strategies for a number of tropical species- *Pinus caribaea*, *P. oocarpa*, *P. tecunumanii*, *P. patula*, *P. kesiya*, *P. merkusii*, *P. greggii*, *Agattiis* spp., *Cupressus* spp., *Widdringtonia* spp., *Cedrela* spp., *Cordia alliodora*, *Liquidambar styracifua*, *Leucaena* spp., *Prosopis* spp. and *Acacia* spp., etc.

8) U.S. Department of Agriculture's Forest Service and State Programmes

- The activities of the U.S. department of Agriculture's Forest service include research and genetic improvement programs conducted in national forests.
- Research is primarily aimed at species of high commercial value, but there is growing emphasis on maintaining the diversity of forests.

- Individual states have independent conservation programmes. Conifer germplasm conservation project is designated to provide information and resources needed for long term protection of the diversity of forests. It is working on *Pinus taeda*, *P. ponderosa*, *Pseudotsuga* spp., etc.

9) NATIONAL RESEARCH CENTRE FOR AGROFORESTRY (NRCAF)

- Its head quarter is in Jhansi, UP, India
- To under take basic and applied research for developing and delivering technologies based on sustainable agroforestry prctices on farms, marginal and wastelands for different agroclimatic zones in INDIA
- To co-ordinate network research with the SAUs/ ICAR Institutes/ other related research institutes for identifying technologies which can be transferred from one region to another.
- To provide training in (a) research methodologies and (b) use and application of technologies developed at various levels.
- To develop technological packages of diffrent agroforestry practices for various agroclimatological zones for transfer to farm field and wastelands.
- To act as repository of information on the subject.
- To collaborate with relevent national and international agencies for achieving the mandate.
- To provide consultancy.

10) INDIAN GRASSLAND AND FODDER RESEARCH INSTITUTE (IGFRI)

- Based in Jhansi, UP, India
- To conduct basic, strategic, applied and adaptive research; development and training in forage production and it's utilization.
- Is the premier R&D institution in South Asia for sustainable agriculture through quality forage production for improved animal productivity.

LECTURE - 10

LEARNING OBJECTIVE: TO KNOW ABOUT MULTIPURPOSE TREE SPECIES (MPTs) AND THEIR MANAGEMENT

MUTIPURPOSE TREE SPECIES

The multipurpose tree species (MPTs) is a plant species that are purposefully grown so as to provide two or more than two products and also a service functions like shelter, shade, land sustainability of the land-use system. Many woody perennial species may be 'multipurpose' in one kind of system but 'single purpose' in another.

VARIOUS BENEFITS FROM MPTS

FOOD

1. Human food from trees (fruits, nuts, leaves, cereal substitutes, etc).
2. Livestock feed from trees (one step down the tropic chain).
3. Fertilizer trees for improving the nutritional status of food and feed crops through:
   (a) Nitrogen fixation
   (b) Access to greater volume of soil nutrients through deep rooting trees
   (c) Improved availability of nutrients associated with higher cation exchange capacity and organic matter levels.
4. Soil and water conservation.
5. Environment amelioration.

WATER

1. Improvement of soil moisture-retention in rain-fed cropping systems and pastures through improved soil structure and microclimate effects of trees.
2. Regulation of stream flow for reduction of flood hazard and more even supply of water, through reduction of run-off and improvement of interception and storage in infiltration galleries, through various watershed protection practices involving trees.
3. Protection of irrigation works by hedgerows of trees.
4. Improvement of drainage from waterlogged or saline soils by phreatophytic trees.
5. Increased biomass storage of water for animal consumption in forage and fodder trees (higher water content of tree fodder in dry season).

ENERGY

1. Firewood for direct combustion
2. Pyrolytic conversion products (charcoal, oil, gas).
3. Produces gas from wood or charcoal feedstocks.
4. Ethanol from fermentation of high-carbohydrate fruits.
5. Methanol from destructive distillation or catalytic synthesis processes using woody feedstock.
6. Oils, latex, other combustible saps and resins.
7. Augmentation of wind power using appropriate arrangements of trees to create venturi effects (wind power is proportional to the cube of wind velocity).

SHELTER

1. Building materials for shelter construction
2. Shade trees for humans, livestock and shade-loving crops.
3. Wind-breaks and shelter-belts for protection of settlements, cropland
4. And pasture.
5. Living fences.

RAW MATERIALS FOR PROCESSING

1. Wood for a variety of craft purposes.
2. Fibre for weaving industries.
3. Fruits, nuts etc. for drying or other food-processing industries.
4. Tannins, essential oil, medicinal ingredients etc.

CASH

1. Direct cash benefits from sale of above-listed products.
2. Indirect cash benefits from productivity increases (or input savings)
3. Via associated crops or livestock.

SAVINGS INVESTMENT

1. Addition of a viable emergency saving or investment enterprise to farms now lacking one.
2. Improvement of exiting savings/investment enterprise (e.g., fodder for cattle as savings on the hoof).

SOCIAL PRODUCTION

1. Production of goods for socially motivated exchange (e.g. cattle for bride price, ceremonial foods etc.)
2. Increased cash for social purposes (ritual expenses, development levels, political contributions etc.)

CHARACTERISTICS OF MPTS

Multipurpose trees species should fulfil the following criteria:

- Wider adaptability to local climatic conditions.
- Thin and sparse crown that allows sunlight enter into the system
- Capacity to withstand various management practices like coppicing, lopping and pollarding etc.
- Quick sprouting habit.
- Productive capacity that includes poles, wood, food, fodder, medicinal and other products.
- Good leaf litter making nutrients available at appropriate times in the crop cycle.
- Few and shallow lateral roots (or prunable).
- Ability to assist in nitrogen fixation.
- Resistance to drought, flooding, soil variability and other climatic hazards.
- Deep thrusting taproot system.
- Easy to manage
- Cheap to establish
- Higher demand and better value for the produce.

MANAGEMENT STRATEGY FOR MPTS

- Having chosen the forestry and agricultural components of an agroforestry system suited to the site the management strategy which maximizes the value of the system must be developed.

- Probably the most important factor affecting the management strategy is the nature of the relationship between the over-storey of trees and the agricultural under-storey.
- **Management in horizontal dimension (water and nutrient limiting)**
    - Changing spacing
    - Zonal arrangement-Macro/micro
    - Mixed cropping
- **Management in vertical dimension (light limiting, nutrient and moisture in plenty)**
    - Growing species at different times
    - Growing species of different heights in such manner that smaller mature before tallest one
    - Under storey crops can be given extra light at certain times of the year depending upon leaf fall or by tree pruning
    - Growing species which attains similar heights but with different life cycle
- **Management in time dimension**
    - If component not fully utilize environmental resources available throughout the year, yield can be increased skillfully by:
        - Choosing species and cultivars according to phenology, stature, habit, produce etc.
        - Staggering planting, relay planting etc
- **Management practices: (**for tree crops)
    - Initial tree spacing
    - Management practices
        - Thinning, pruning, coppicing, pollarding, bending, bushing etc

INITIAL SPACING

- Dependent on growth rate of the trees
- Final crop stock depends on
    - Relative value of the tree and agriculture crops
    - Environmental factors affecting availability of nutrients, moisture and soil space
    - Latitude and aspect which affect the availability of incoming radiation
    - Performance of tree crop
    - Performance of agriculture crop
    - Management considerations-machinery
    - Personal preferences

MANAGEMENT PRACTICES

Thinning

Felling made in immature stand for the purpose of improving the growth and form of the trees that remain without permanently breaking the canopy. It is mainly done:

- To improve the hygiene of the crop by removing dead, dying and diseased trees
- To ensure best physical conditions of growth
- To obtain a desired type of crop
- To improve the stand composition and afford protection from the spread of insects and diseases
- To improve the quality of wood
- Increase the net yield and financial return from the crop

Pruning

- Removal of live or dead branches or multiple leaders from standing trees for the improvement of the tree or its timber.
- It allows the grower to manipulate the growth and development of the trees left after thinning to improve the quality of the tree and to increase agriculture returns
    - Natural; natural death and fall of branches of standing trees grown closely due to deficiency of light or decay etc
    - Artificial: Removal of branches with sharp tools in a dense crop.
    - Pruning lower branches close to the trunk of tree makes small knotty core which gives clear straight grain timber.
    - Removal of too many branches will retard the growth
    - If pruning is left too late, the central core of knotty wood become large thus reducing value of tree

Pollarding:

Pollarding consists of cutting a pole tree at some height above the ground level so that it produces new shoots from below the cut. Pollarding is done at a height of 2- 2.5 m above ground level; e.g. in *Salix* spp., *Hardwickia binata, Grewia optiva, Morus alba,* etc.

Lopping:

Removal of one year shoots or fresh growth from entire crown of the tree/plant in order to get sufficient fodder for livestock is known as lopping. Lopping is extensively done in *Morus*, *Grewia*, *Bauhinia,* etc.

Coppicing:

Cutting or heading back of main stem at 30 cm from the ground level. **Strong coppicers**: *Acacia catechu*, *Albizia lebbek*, *Anogeissus latifolia*, etc.; **Good coppicers**: *Aesculus indica*, *Chloroxylon swietinia*, *Hardwickia binata*, etc.*;* **Bad coppicers**: *Adina cordifolia*, *Bambax ceiba*, etc.; and **Non coppicers**: All conifers.

Bending:

Restricting the development of bole to allow more food material to new leaf shoots. Bending and coppicing are useful when it is desirable to produce large quantity of foliage close to ground level.

Training:

In agroforestry vertical spread of the tree is a desirable feature, therefore trees raised in agroforestry systems must be vertically trained to avoid shade and light competition to underground crop.

Bushing: Horticulture operation commonly used to increase fruit production at a convenient height for harvesting.

LECTURE - 11

LEARNING OBJECTIVE: TO KNOW ABOUT NURSERY, NURSERY TYPES, IMPORTANCE OF NURSERY AND CRITERIA FOR NURSERY SITE SELECTION

DEFINITIONS

- **Nursery** is defined as an area where plants are raised for eventual planting out.
- **Nursery composition**: It comprises of nursery beds, paths, irrigation channels, etc.
- **Nursery bed** is defined as a prepared area in a nursery where seeds are sown, or into which transplants or cuttings are put. On the basis of the kind of plants growing in them, nursery beds are classified into **Seedling Beds** and **Transplant Beds**.
- A nursery which has only seedlings beds, i.e. in which only seedlings are raised, and no transplanting being done, is called **Seedling Nursery**.
- **Transplant beds** are those nursery beds in which seedlings raised in seedling beds are transplanted before planting out in forest. A nursery which has only transplant beds, i.e. in which seedlings are transplanted in preparation for forest planting is called **Transplant Nursery**.
- In India, separate seedling and transplant nurseries are seldom made; in the same nursery, some beds are seedling beds and others as transplant beds. Generally, whatever is grown in a nursery for planting out is called **Nursery Stock**. This term is also used for plants supplied from a nursery.

IMPORTANCE AND OBJECTIVES

Nursery occupies an important place in artificial regeneration. The increase in artificial regeneration works in general and the efforts to raise fast-growing, short rotation crops involving introduction of exotics in particular, have further increased its importance. The following objectives for which nursery is generally made, clearly bring out its importance:

1) Some important species do not seed every year. Plantations of these species can be raised annually only by collecting all available seeds in years of moderate and good seed years and sowing it in nursery to raise seedlings to be planted out in various years.

2) Some species grow very slowly and if the seed of these species is sown directly in plantation area, the seedlings are most likely to be swamped by weeds and killed. Therefore, slow-

growing species are generally raised in nursery and planted out only when the seedlings are not liable to be damaged by weeds.

3) Success of roadside avenue plantations depends largely on planting tall and sturdy plants which can be obtained from a nursery.

4) Plantations of some species when raised by direct sowing are not as successful as when raised by planting. In such cases, nursery is an essential part of artificial regeneration of those species.

5) The best method of introduction of exotics, viz. tropical pines, poplars, eucalyptus, etc. is only by planting and therefore nursery is very essential for them.

6) Planting of nursery grown plants is the surest method of artificially regenerating poor and barren sites.

7) Casualties in plantations have to be replaced either in the year of plantation or in the next year. Sowings done in the gaps are liable to be unsuccessful as a result of suppression from weeds and can not catch up the plants from original sowing. Therefore, replacement of casualties is always done by planting nursery-grown plants or stumps and so nursery is very essential for casualties' replacements.

CLASSIFICATION OF NURSERIES

Nurseries are classified either on the basis of irrigation facility/moisture content or the duration of their use.

A) ON THE BASIS OF IRRIGATION FACILITY NURSERIES ARE CLASSIFIED INTO:

a) DRY NURSERY: It is a nursery that is maintained without any irrigation or other artificial watering.

b) WET NURSERY: It is a nursery that is maintained by irrigation or other artificial watering during the dry periods.

B) ON THE BASIS OF DURATION OF THEIR USE NURSERIES ARE CLASSIFIED INTO:

a) TEMPORARY NURSERY

It is a nursery that is maintained for supplying nursery stock for a short period after which it is abandoned. Normally it is made in the plantation area or in previous year's plantation if it is close by. It is also referred to as **field nursery** which is defined as a temporary nursery found in or adjoining the planting area. As it is intended to meet the requirements of a limited area, it is usually small in extent.

ADVANTAGES OF TEMPORARY NURSERY:

It is usually made in newly cleared sites fairly rich in humus, and therefore does not require any manuring. *Eucalyptus* hybrid nurseries are an exception to the general rule. There is minimum trouble with the weeds, destructive insects and diseases. It enables raising of species in their optimum altitudinal zone in hills. It also enables easy, quick and cheap transport of planting stock without any serious damage or shock.

DISADVANTAGES OF TEMPORARY NURSERY:

As it is made in out-of-way places, proper supervision is not possible. In the absence of irrigation facility, the growth of seedlings is, usually, slow and there is usually heavy mortality in them. It is relatively costlier to maintain as compared to a permanent nursery.

b) PERMANENT NURSERY

It is a nursery that is maintained for supplying nursery stock for a long time on a permanent basis. The duration of services and life of permanent nursery is long and it is maintained till seedlings can be raised in it at reasonable cost. As it is intended to meet the requirements of one or more ranges, it is relatively larger and near to the headquarters of some subordinate for proper supervision. It should be on or near some road for quick and easy transport of nursery stock. As plants are raised year after year for long time, its initial fertility dwindles and it has to be manured regularly. It has facilities for irrigation and shading of plants.

CRITERIA FOR NURSERY SITE SELECTION

i. Nursery should be selected as carefully as possible with reference to the area to be planted.
ii. It should preferably be near a Ranger's or Forester's residence for close and regular supervision.
iii. It should be close to the source of supply of labour to do various works as and when required.
iv. In order to have good irrigation facility, it should be situated near or slightly below the source of adequate water supply.
v. Soil should be well drained sandy loam. Clayey soils should not be selected as their aeration and drainage is poor and they are liable to crack during summer.

vi. As far as possible, it should be made in a newly cleared forest land, with no overhead shade from the south.

vii. It should never be located in a natural blank.

viii. In the hills, a gentle slope not exceeding 5° should be selected. If the slope is steeper, cost of terracing increases.

ix. In the Western Himalayas, northern aspect should be preferred, but towards higher limits of the altitudinal zone of the species southern aspects are suitable, that only up to an altitude of 1200 m; beyond that they become too cold and wet, and so western or south-western aspects are preferred.

x. Altitudinal zone of the species should also be kept in mind while selecting site for nursery in hills.

LECTURE - 12

LEARNING OBJECTIVE: TO KNOW ABOUT ECONOMICS OF CULTIVATION-NURSERY AND PLANTING OF

*Acacia catechu.*Willd.

Plate 12.1(a) *Acacia catechu* tree

Plate 12.1(b) Leaves and pods

Botanical name **:** *Acacia catechu* Willd.

Common name **:** Khair, Kath tree, Cutch tree

Family **:** Leguminosae

Sub Family **:** Mimosoideae

Description

- A moderate sized deciduous tree with light feathery crown with crooked brown bole,
- Bark dark brown and red inside
- Branches are glabrous armed with recurved thorns
- The species is distinguished into three distinct varieties viz. *Acacia catechu*, variety catechuoides, variety sundra and variety catechu.

Distribution

- It is found throughout India except in humid and temperate region.
- It is widely distributed between 900-1200 m from Jammu to Assam.

- Variety catechu is found in Sikkim, Tarai, West Begal, Assam and upper Mynmar.
- Variety sundra is found in Indian Peninsular region and parts of Burma.

Climate

- Temperature - Maximum 40°C -50°C; Minimum 1°C
- Rainfall - 500mm to 2000mm
- Altitude - 1200m

Soil

- *Acacia catechu* grows on wide variety of soils such as sandy, gravelly alluviam, loam with varying proportions of sand and clay and black cotton soils.
- It is capable of growing on shallow soils with *murram* or *kankar* on which few other species can grow.

Phenology

- Leaf-fall - January-February
- Leaf renewal - April-May
- Flowering - April to August
- Fruiting - September-October
- Seed collection – October-November, December

Silvicultural characters

Strong light demander, frost and fire hardy, wind firm, browsed by animals.

Regeneration

Natural regeneration

- *Acacia catechu* reproduces naturally through coppice as well as from seed.
- The coppicing power of the trees depends upon their age, vigour, season of cutting and site conditions.
- In its stands of normal growth and stocking, coppicing can be relied upon to regenerate this species. Such stands are worked under coppice system.
- The stocking of the coppice crop, which depends upon the stocking of the natural crop coppiced and the coppicing power of the trees, is generally irregular.

- Coppice regeneration has therefore to be supplemented by artificial regeneration.
- Coppicing cannot be relied upon in selection stands where *Acacia catechu* grows mixed with other species as the light sufficient for the development of coppice shoots dose not reach the ground in such forests.
- Under heavy shade the stools normally do not coppice.
- The stand having over mature trees also cannot be regenerated through coppice because of the weak coppicing power of such tree.
- It has, however, been observed in some areas that the size of the stump does not affect the coppicing power and the stumps up to 60 cm diameter not only coppice well but also produce healthy coppice shoots.
- The growth of crop is faster than that of the seedlings crop; an average girth of about 20 cm and an average height of about 3.4 m can be expected for nine years old coppice.
- Coppice crop, however, requires thinning of stool to reduce the competition which may otherwise very adversely affect the growth rate of coppice shoots.
- Natural regeneration through seed can be expected under favourable conditions only.
- Seeds, are disseminated by wind. Germination takes place with the onset of monsoon rains and the seedlings get established where conditions are favourable for their growth.
- Soil type, drainage, weed competition, shade and grazing are important factors determining the success of natural regeneration through seed.
- Poor drainage coupled with shade results in heavy mortality of the seedlings because such conditions encourage damping-off. Tall and gregarious weeds compete out the seedlings.
- Grazing does not permit any natural regeneration to establish as the seedlings are browsed and killed. Profuse natural regeneration may be expected in areas kept free of grazing.
- It may be totally absent in grazed areas.
- The growth of seedlings in naturally regenerated crops is slow and they often die-back in winter

Artificial regeneration

Acacia catechu can be propagated by one of the three methods, namely (1) direct sowing, (2) planting out nursery raised seedlings and (3) stump planting. Direct sowing is better than stump planting, which is preferred to planting out of entire plants without containers.

i. Line/strip sowing in lines 60 to 90 cm apart, strips 2.5 to 3 cm apart.
ii. Broadcast sowing in weed free area.
iii. Patch sowing by dibbling 2.5 to 3 cm apart.
iv. Potted plants or with ball of earth.

Seed collection and storage

- The seed ripens in November-December or early January
- Seeds are very susceptible to insect attack even when on the trees and the pods should, therefore be collected shortly before the seeds are fully ripe as otherwise most of seed crop may be destroyed by insects.
- The pods are dried in the sun and then thrashed to separate the seed which is properly cleaned, dried in the sun and stored in airtight tin containers. The seed should preferably not be stored for more than 6 to 8 months under ordinary conditions;
- The seed should preferably be sown during the year of its collection. As *Acacia catechu* is a good seeder, there should be no problem in the collection of sufficient fresh seeds every year.
- About 30 to 40 seeds weigh one gram.
- Seed yield per tree is about 0.5 to 2.0 Kg.

Nursery technique

- Sowing is done in February-March in well prepared nursery beds.
- The spacing adopted is 20 cm between the lines and 2 cm between the seeds in the lines.

Planting technique

a) Polybag plants:

- A pit of $30cm^3$ is prepared with a spacing of 3m × 3m about 2 months in advance
- Planting is done in the month of July
- Polythene container must be removed at the time of planting

b) Ball of the earth planting:

- The taproot is cut at a depth of 25-30cm at the time of uprooting of seedling

- Splitting or bruising tap root is avoided
- Transplanting of seedling is done in rainy season as winter entire transplant are failure

c) Stump planting:

- Stumps are prepared from 12-15 month old seedling
- The root and shoot portion should be 23-31cm and 2.5 to 5.0cm respectively.
- Stump less than 1cm collar diameter give poor survival
- Stump can be stored for 3 days
- Planting of stump should be done in the onset of monsoon

Silviculture system for management

The best system under which khair is managed is the clear felling followed by artificial regeneration.

Disease

Ganoderma lucidum causes root rot disease with considerable mortality in khair plantation raised after clearfelling.

Economic importance

- Heartwood is mainly used for katha extraction
- Timber is mainly used for agriculture implements
- Small branches for fuel-wood
- Leaves as fodder for goats
- Gum is also important product obtained from *Acacia catechu* and regarded as the best substitute for the gum-arabic

SIMPLE QUESTIONS TO BE ANSWERED

1) Phenology refers to

a) Leaf fall c) leaf renewal

b) Flowering d) All of these

2) *Acacia catechu* is ……. Species

a) Strong light demander c) Shade loving

b) Shade bearer d) None of these

3) Variety sundra of *Acacia catechu* found in …..

a) Indian Peninsular region c) North-East states

b) Himalayan region d) None of these

4) *Acacia catechu* is …..

a) Strong coppicer c) Bad coppicer

b) Non coppice d) None of these

5) Katha is obtained from

a) Leaves c) Pods

b) Roots d) Heartwood

KEYS FOR THE OBJECTIVE QUESTIONS

1) d
2) a
3) a
4) a
5) d

LECTURE - 13
LEARNING OBJECTIVE: ECONOMICS OF CULTIVATION-NURSERY AND PLANTING OF *Populus deltoides Bartr.*

Botanical Name : *Populus deltoides* Bartr.
Family : *Salicaceae*
Local Name : Poplar, Pharipipal

Plate 13.1 Poplar tree

Introduction

- Poplars are amongst the fastest growing tree species under appropriate agro climatic conditions.
- Poplars can be harvested at short rotations of 8 to 10 years.

- Wood obtained from poplars is eminently suitable for manufacture of match splints, veneering products, artificial limbs, interior paneling, cheap furniture and packing cases etc.
- Poplars with straight and cylindrical bole, moderate conical crowns mostly deciduous during winter months,
- Combine well with inter-cultivation of agriculture crops.
- These features combined with good economic returns and availability of long-term bank loans have made versatile poplars the most popular tree species for planting under agro forestry system in the irrigated tracts of north-western plains of India
- Six indigeneous species viz *Populus ciliata, P. laurifolia, P. gamblei, P. alba, P. glauca,* are found along water courses in Himalayan region.
- However, success story of poplar plantations in the north-western plains of Uttar-Pradesh, Haryana, and Punjab is based on exotic *P. deltoides* indigenous to United States of America.
- Certain clones of *P. deltoides* have been found to be eminently suitable for a afforestation as well as agro forestry plantation. *P deltoides* clones G-3, G-48 (Australian selections) and D-121 (American selections) constitute bulk of these plantations.
- Additional clones like D-61, D-67, S-7C-8 and S-7C-15 have also been included in the plantation programme. Poplars can attain 90 cms girth at breast height and mean annual increment of $20m^3$/ ha at 8 years rotation under good care.

Description

- *Populus deltoides* is a fast growing tall tree with a fairly straight and slim trunk, rather open crown composed of a few large branches and attaining a height of 30 m and girth of 2 m.
- The branches are more or less angled or almost winged, the side branches borne on large branches are shed early.
- Outer bark forms early, furrowed by cork-like ridges and deep fissures.
- The leaves are fairly large, deltoid on short shoots and very large and cordate on long shoots, light green in colour.
- They are 10-18 cm long, acuminate, crenate-dentate with long petiole.

- The male catkins 7-12 cm long, 40-60 stamens per flower and produce wind-borne pollen. The female catkins are 15-25 cm long.
- The female flowers have single-celled ovary with numerous ovules and at anthesis have 2-4 prominent stigmas.
- Fruit ovoid capsules, hanging in loose clusters, opening by 3-4 valves and seed is small and hairy.

Distribution

- *P. deltoides* clones have been cultivated in a number of countries.
- In fact, *P. deltoides* and their hybrids together make about 90 percent of the total cultivated poplars of the world (FAO, 1979).
- Among the countries in which they have been cultivated are West Punjab in Pakistan, Middle East, New South Wales in South Australia, Parana Delta and north eastern continent part of the province of Buenos Aires, Argentina (Singh, 1982).
- In India, it has been successfully cultivated as a forest crop or agroforestry crop in the Punjab plains and in the Terai region of Uttar Pradesh.
- Poplars have been raised at slightly lower latitudes also, but it is only above 28˚ N, that they had fair success in experimental plantations and on farms.
- On experimental scale, *Populus deltoides* has been successfully cultivated at Jorhat (Assam) at an altitude of 96.5 m (Sharma and Bardoli, 1986).
- In its natural range in the southern part of USA, *P. deltoides* occurs primarily on bottom lands along rivers and other water ways (FAO, 1979).
- In West Punjab (Pakistan) and Middle East, it is cultivated only where irrigation is available.
- In areas where its cultivation has been tried without irrigation, the growth has been very poor.
- In not adequately irrigated plantations in the Middle East, *P. deltoides* is reported to become susceptible to the major wood borer *Melanophila picta* (Singh, 1982).

SOIL

- *Populus deltoides* can survive on soils varying from sandy loam to fairly stiff clay, but it makes its best growth on moist, well-drained, deep, medium-textured, alluvial soils that are fertile and well-aerated (Baker and Broadfoot, 1976).
- The nursery plants perform better on clayey soil than on sandy soil (Bonner, 1967). Coarse sands and heavy clayey soils deficient in organic matter are unsuitable.

Artificial Regeneration: Poplars can be raised by the following methods.

(i) By Sexual Reproduction:

- The tree produces seed at intervals but it has low germination percentage.
- The seed of *Populus deltoides* has been germinated under laboratory conditions with germination percentage varying from 5.25 to 19.25%.
- The medium of germination, i.e. two parts soil and one part is of river sand duly sterilized proved most effective and gave higher survival and best shoot development.
- Germination tests conducted about the viability of seed after 6 years of storage showed that -20˚C storage was superior to -50˚C storage in maintaining seed viability (Tauer, 1979).
- *Populus deltoides* flowered for the first time in May, 1982 in Terai (U.P.).
- Poplar seeds are very minute and 14,000 seeds weigh one kg (Beniwal and Singh, 1989).
- The plant is rarely raised by seeds.

(ii) Vegetative propagation:

- *Cuttings*

  Cuttings 18-25 cm long and 1-2.5 cm thick having at least four buds are directly planted in the field in well worked soils, keeping one bud above the ground. The soil around the cuttings is thoroughly compacted.

- *Sets*

  A set is one year old cut back plant without root or a long stem cutting which consists of one year growth. The root portion left in the nursery can again be used to produce

plant/set/cuttings for the next planting season. Sets are planted in 75 cm to 1 m deep pits. The length of set is about 3.5 m or more.

- *Bag plants*

  These can be raised in polythene bags of 15cm x 23cm x 150 gauge filled with soil mix and treated with 5% aldrex. Cuttings are planted in these bags in February in the year of planting. Vigorous plants are not obtainable by this method.

- *Stumps* (Root-shoot cuttings)

  These are prepared from one year old nursery plants keeping 25 cm long root and 3 cm of shoot.

- *Entire transplants* (ETPs)

  This is the best method for transplanting poplars. These are one or two year old plants raised from cuttings in the nursery. While removing these plants, the root is cut at 25 cm depth and all side roots more than 10 cm long are also trimmed. The plants are taken out with naked root and without foliage.

Nursery Techniques

i) ***Site Selection***

- Soil type and irrigation facility are the two important considerations for the selection of site for nursery.
- Poplar (*Populus deltoides*) needs preferably sandy loam, deep, fertile, well drained, neither alkaline nor too acidic, free from underlying impervious layer and rich in organic matter.
- Coarse sand in areas where the water table drops below in winter and which are subject to summer drought, soils with top-layer removed by erosion and site with laterite occurring within 60 cm of surface are considered unfit for poplar cultivation.
- Assured irrigation is essential besides other requirements of a good nursery site. As poplars are very sensitive to zinc deficiency, zinc sulphate @ 25 kg/ha should be applied in the area at the time of site preparation (Lal, 1991).

Site Preparation **:**

- A light preparatory irrigation should be given so that the soil has proper moisture at the time of ploughing.
- The field should be levelled after ploughing. One deep ploughing upto 25-30 cm depth is desirable.
- Phosphatic and Potassium fertilizers should be added at this point. After addition of fertilizers, one more harrowing should be arranged.

Clones:

A lot of good quality clones have been developed and launched commercially. Some of them are G-48, S_7C_{15}, S_7C_8, L-34, L-49, L-52, Uday, Kranti, WS-39, WSL-22, WSL-27, WSL-32, WSL A-49, and PL-1 to PL-7 etc.

ii) ***Selection of cuttings***

- Cuttings from the main stem of the *Populus deltoides* give better results than those obtained from branches.
- One year old plants from existing nurseries are used for preparation of cuttings for the new nurseries.
- Diseased, dying off-type and suppressed plants must be culled from the beds where stock is reserved for preparation of cuttings for the new nurseries.
- The plants can be cut 2 cms. from ground level and the resultant sets should be graded and formed into bundled and should be transported to the new nursery site immediately and stored there in the storage pits, which should be kept full with fresh water to be replenished every day.
- Cuttings made from ripened one year old wood of the main stem give better results.
- Only well lignified shoots should be used; too tender shoots are not suitable for cuttings.
- Cuttings obtained from young, healthy and vigorous plants perform better.
- The length of cuttings should be 18-25 cm and these should contain four buds.
- When cuttings are taken from the trees, the age of trees and of the parts of trees from which the cuttings are taken markedly affect rooting (Zsuffa, 1976).

Preparation of cuttings

- Cuttings should be prepared with a very sharp and fairly heavy tool to obtain a very clean and smooth cut.
- During the preparation of cuttings, the cut must be given at a point of the set which is fully supported on a log/beam of wood to prevent splitting of cuttings.
- Maximum number of available cuttings from each plant down to one centimeter diameter can be used for planting.
- All cuttings must be submerged under fresh water in drums immediately after preparation of the cuttings.

Treatment of cuttings

- Before planting, cuttings are soaked in water for 24 hours
- Cuttings should be treated with Aldrin (250 ml of Aldex 30 EC in 100 litres of water) and thereafter Emisan (250 g in 100 litres of water) for 10 minutes each and then only planted in the nursery.

iii) ***Planting of cuttings***

- For production of healthy and vigorous entire plants, planting of cuttings at 80 cm x 60 cm is the best spacing (Chaurvedi, 1981).
- To produce one year old plants, spacing of 1-1.4 m between the lines and of not less than 40 cm between the plants is normally adopted (FAO, 1965).
- The best time of planting cuttings in the nursery is January to February.
- Cuttings made earlier than January and later than March do not perform well in open conditions (Chaturvedi, 1981).

Plate 13.2 Poplar nursery

- Planting rods with the lower ends flattened and sharpened like a screw driver should be used for making the planting holes.
- Each cutting with its thinner end up should be planted in the hole in such a way that the upper portion is just 2 cms above the ground level.
- After planting the soil around each cutting should be compacted gently but firmly without injuring the bark of the cutting in any way.

Irrigation in Nurseries

- Irrigation should be provided as soon as the planting of cuttings in any bed is completed.
- The first irrigation should be medium heavy so that about 5 to 7 cms water is uniformly above ground level at the time of irrigation.
- Soil moisture in the nursery bed should be kept high during rooting of cuttings.
- Subsequent irrigation should be light and the interval may vary between 7 to 10 days depending upon the type of soil.
- Light sandy soils will need frequent irrigations whereas medium to heavy soils will need irrigation at longer intervals.
- The top soil should not be allowed to develop cracks and become absolutely dry.
- Irrigation should be applied at 10 to 15 days interval depending upon the type or soil and need of individual nurseries till onset of monsoons.

- Proper and effective drainage of excess water during rainy reason is essential to prevent lodging and collar rot.
- After the rainy season one to two irrigations per month is adequate.

***Fertilizer application*:**

- As the poplar plants grow very fast, the nursery soil has to be enriched frequently. Urea, Super phosphate, Murate of Potash and plentiful supply of Farm Yard Manure are essential for maintaining the growth of cuttings.
- Application of well decomposed compost or farm yard manure @ 200 to 250 quintal per hectare nursery area at the time of soil working is very helpful for the growth of poplar.
- The quantity of fertilizer will depend upon the type of soil.
- Nursery beds are depleted of fertility after producing plants for one year, if no fertilizer is applied.
- After the rains have set in, 2g of urea per plant is given;
- Regular debudding and hoeing will depend upon the incidence of weeds and grasses.
- Singling of collar shoots should be done during April-May when the most vigorous shoot has attained a height 30-35 cm.
- Debudding is done by gently rubbing with gunny bags the newly formed buds upto 2/3 rd height of plant from the base from June to October.
- Sufficient care should be taken to ensure that the young leaves are not damaged.

Planting Entire Transplants (ETPs)

- The best time for planting poplar is during the months of January-February before the opening of new buds. One year old ETPs of 3 m length containing 25 cm root portion give most satisfactory results.
- The depth of planting will depend upon the soil type, depth of water table, size of planting stock, etc.
- As poplar is a fast growing species, the soil requires to be incorporated with fertilizers
- A basal dose of 2 kg good FYM, 50 gm super phosphate and 5 gm urea per plant is needed. Nitrogenous fertilizer should be applied in split doses, first dose of nitrogen as 75

g urea should be applied during the first week of June, second dose of 150 g urea during first week of July and third dose of 250 g urea during second and third week of August.

- Application of fertilizer must be followed by light irrigation.
- The best spacing under agro-forestry systems is 5 m x 4 m *i.e.* 500 plants per hectare.

Application of Manure and Fertilizers

Well decomposed farmyard manure which is rich in macro as well as micro nutrients essential for the plants should be applied to the total area under poplars while preparing the land for inter-cultivation of Rabi and kharif crops. Application of nitrogenous potassic and phosphatic fertilizers as well as micro nutrients will depend on the fertility status of the land. 50 gms of single super phosphate 25 gms muriate of potash is used at the time of planting.

Inter-cultivation of Agricultural Crops

Any traditional crops except paddy can be grown reasonably well in between the lines of poplars during the first 2 years. Subsequently shade tolerant crops like ginger, turmeric and colocasia can be raised as less sunlight penetrate to the ground during active growth period of poplars because the crowns cover most of the canopy. Short duration winter vegetables or rabi crops like wheat lentils toria etc. can also be raised as most poplar clones are leafless during autumn. However intercrop yield decreases with the increase in age of poplars. Care should be taken to avoid physical injuries to the stem of poplars during inter-cultivation operations.

Inter-cropping :

It is desirable to grow field crops as inter crops in block plantations of poplar. All *rabi* and *kharif* crops can be grown during the first three years except paddy. However, inter-cultivation of sugarcane be preferred for first two years as it is more profitable. Third year onwards cultivation of wheat, cabbage, chilly, tomato, barley, coriander, turmeric, ginger, strawberry, oats, berseem, sarson etc. can be raised throughout the rotation.

Plant Protection Measures :

Certain insects and pathogens are known to damage the poplars. Among the important ones are the following :

- Leaf defoliator : These are active during the rainy season particularly *Pygaera* species. The caterpillar of these moths feed on leaves. The insect can be controlled by collecting and destroying the infested leaves. Spray of Monocrotophos 36 SL @ 600 ml (Monocil / Monolik / Nuvacron / Corophos / Luphos) per acre.
- Termites : The risk of termite damage is likely where irrigation and inter cultivation operations are inadequate. The soil should be treated with Aldrin or Gammexene (BHC) (0.15%) and frequent irrigation arranged.
- Stem and shoot borer : These can be controlled by pushing a small wick of cotton dipped in any liquid fumigant in the holes through which frass is being pushed out by the borer. All holes must be closed with mud paste after such treatment.
- Leaf Webber : The young larvae scrap the leaf surface along with veins and feed on epidermis of leaves by webbing 2 and 3 leaves with silken threads. The pest is active from April to November with peak period from July to October. For controlling the same measures as indicated under leaf defoliators can be adopted.
- Bark Eating Caterpillar : Nocturnal feeding larvae make L-shaped holes and wet silken threads entangled with fecal pallets. Pest is active throughout the year. Prune severely infested branches and spray suspension of 100 g Carbaryl 50 WP (Sevin / Hexavin) in 10 litres of water during September to October at feeding sites.
- Case Worm : The pest is active throughout the year. The caterpillars feed on bark from December to March, on leaf buds during March and April and on leaves from April to November. For controlling this a spray of Carbaryl 50 WP (Sevin / Hexavin) @ 1 Kg per acre is recommended.
- Leaf Hopper : The leaf hoppers are active from April to November with peak period of their activity from July to October. A spray of Oxydemeton-methyl 25 EC (Metasystox) @ 300 ml or dimethoate 30 EC @ 250 ml per acre is recommended.
- Rot of cuttings : Black dots appear on the cuttings at ground level and decay of bark takes place. Dip the cuttings for 15 minutes in 0.5 percent solution of Emisan-6 before planting.
- Leaf Spots : Brown to dark brown leaf spots of variable sizes appear on leaves. Severe infections lead to premature defoliation. Spray the crop with 0.25 percent Copper Chloride (Biltox 50) or Indofil M-45 at 15-20 days interval starting with first rain. Two to three sprays may be given.

- Pink Disease : Girdling of branches in young plants leads to death of parts. The height of tree is stopped due to repeated death of the leaders. Pink to Salmon colored mycelial growth appears on branches. Use resistant varieties or two to three prophylactic spray of Bordeaux mixture during two to four years of age at the beginning of the summer monsoon.
- Sunscald canker : Bark is killed due to insolation by heat and canker develops on the southern side of the stem. Protect from insolation and other injuries by white washing the main stem upto two meters from the ground level.
- Bark Bursts and Canker : Water oozes out through the wounds resulting in cankers. Avoid injury and high water table sites. Clean the wounds and apply Bordeaux paste or Emisan-6.

9. Yield and Returns

- Under reasonably good care poplars can attain 90 cm girth at breast height and mean annual increment of 20m^3/ha (under bark) at 8 years rotation.

10. Utilization

- *Populus deltoides* has a medium hardwood, light, free from knots, easy to saw and work.
- The wood has good nail holding power and strength coefficient of *Populus deltoides* is comparable to well known woods used in packing cases and hence can be used for making cases for fruit and food stuffs.
- High yield pulps (71-80 percent) having excellent strength properties for newsprint could be prepared.
- Young poplars of 2-3 years age group are an excellent source of cellulose fibre for making various grades of fine paper, packing paper, newsprint, etc.
- An experiment conducted at Forest Research Institute, Dehradun indicates that *Populus deltoides* wood is suitable for preparation of hardboards, and that bark to the extent of 20 percent helps in improving the physical and mechanical properties of board compared to boards prepared alone with wood.
- Most of the poplar wood is used in the match and plywood industry.
- The species is suitable for making general purpose plywood, marine plywood, concrete shuttering plywood. It is also considered suitable for the manufacture of artificial limbs,

sports goods and for structural uses such as false ceilings, partition and almirah shelves, etc.

- It has also been found suitable as line supports for overhead power and telecommunication lines.
- The white furniture made out of poplar wood is becoming popular in towns of Punjab.

A-C Zone : Upper Gangetic Plains Region
Situation : Irrigated

Tree-Crop Combination: Agrisilviculture
Tree : *Populus deltoides*
Crops : Paddy, Wheat

Input / Output Analysis

Amount in Rupees

Year	Expenses Per Ha.				Benefits Per Ha.				Net Benefit per Ha.
	Tree	Crop 1	Crop 2	Total	Tree	Crop 1	Crop 2	Total	
1	22000	4320	3360	29680	0	7200	5600	12800	-16880
2	12000	4104	3192	19296	0	6840	5320	12160	-7136
3	12000	3888	3024	18912	0	6480	5040	11520	-7392
4	12000	3672	2856	18528	0	6120	4760	10880	-7648
5	12000	3456	2688	18144	0	5760	4480	10240	-7904
6	12000	3240	2520	17760	0	5400	4200	9600	-8160
7	0	3240	2520	5760	600000	5400	4200	609600	603840
Net Present Value at 15% Discount Factor				82,292				272,533	190,241

Assumptions :

Tree : Populus deltoides : Rotation 7(1)

1. No. of trees/ha. = 500
2. Income per tree : Rs.1200 (in the 7th yr.)
3. Expenses per ha. : Yr.1 = 22000 , Yr.2 & onwards = Rs.12000

Analysis :

Benefit Cost Ratio at 15% Discount Factor : 3.31

Net Present Value in Rs. at 15% Discount Factor : 190,241

IRR : 68%

Crops :

	Rice	Wheat
1. Yield per ha.	1600 kg.	1400 kg.
2. Sale price per kg.	Rs.4.50	Rs.4.00
3. Expenses per ha.	Rs.4320	Rs.3360

Investment

Year 1	Rs.29680
Year 2 to 6	Rs.60000
Total	**Rs.89680**

Note : 1. There is reduction in area under crop from 2nd to 7th year due shade effect of tree
2. Investment includes expenses on trees for 6 years and expenses on crop in the first year.

Source: Report of the task force on greening India for livelihood security and sustainable development. Planning Commission, Government of India, July-2001.

LECTURE-14

"LEARNING OBJECTIVE: ECONOMICS OF CULTIVATION-NURSERY AND PLANTING OF *Morus alba* L. AND *Grewia optiva* Drumm."

Plate 14.1 *Morus alba* tree

Botanical name **:** *Morus alba* L.
Common names (Hindi) **:** Shahtut, tut, tutri, chinni
Family Name **:** Moraceae

Description

A full grown *M. alba* is a moderate sized tree with short clean bole and spreading crown. The bark is smooth in young and rough in old trees. It is a short lived tree and the trunk starts becoming hollow in old trees.

Climate

- *Morus alba* grows in areas with subtropical or mild temperature climate. Maximum shade temperature seldom exceeds 43^0C while the minimum temperature may drop below

freezing point for a few days in January; the absolute maximum shade temperature touches even 48^0C in some areas of its cultivation.

- For optimum growth, adequate water supply, particularly during the growing period, is essential. The annual rainfall varies from about 400 mm to 4500 mm and most of it is received during monsoon season.
- In areas with less than about 1200 mm annual rainfall, irrigation is necessary for its good growth.

Distribution

- *Morus alba* is cultivated in Northern India from Jammu and Kashmir to Assam. In the Himalayas, it ascends up to an elevation of about 1200 m.
- In the hills, it is mostly confined to stream beds or such other places where sufficient moisture is available for its growth.
- It does not grow on dry slopes or shallow soils where moisture becomes the limiting factor.

Soil

- *Morus alba* grows on a variety of soils ranging from sandy loam to clayey loam,
- Alluvial, deep, loamy soil with sufficient moisture supply supports its best growth.
- The tree cannot tolerate alkalinity and grows best on soils with pH ranging between 6.0 and 7.5.
- In hills, moisture availability limits the growth and on dry slopes, the trees remain stunted.

Phenology

- Leaf-fall - November - December
- Leaf renewal - March - April
- Flowering - March -April
- Fruit ripe - April-June
- The fruits are white or red and sweet in taste.
- Trees of about five years age start producing viable seed.

Silvicultural characteristics

- *M. alba* is a shade bearing tree and it can with advantage be grown as an under-storey with other light demanding species.
- It coppices and pollards very well.
- The coppicing power of trees bigger than 30 cm diameter is generally poor.
- It can withstand light frost.
- Its water requirement is high
- It suffers from droughts as may be expected from its being a surface feeder.
- It is susceptible to fire and browsing.

Natural Reproduction

- *M. alba* regenerates either through seed or coppice.
- The seed is dispersed either by water or by birds.
- Such seed as it gets lodged at suitable places, germinates readily.
- For germination, the seed requires moist and well drained soil.
- Light shade is favourable for germination and seedling establishment,
- Thick shade is harmful.
- The seedlings can establish under canopy of trees having light crowns.

Factors considered favourable for seedling establishment are

- Adequate shade,
- Soil free from tall and thick weeds,
- Adequate soil moisture,
- Soil should be free from salinity,
- Protection against browsing animals,
- *M. alba* tends to be aggressive in irrigated plantation areas,
- The tree coppices well and can be regenerated through coppice.

Artificial Propagation

M. alba can be propagated either by planting out nursery raised seedlings or through rooted branch cuttings.

Nursery raised seedlings are planted out either as entire plants or as stumps, the latter give better results than the former.

Direct sowing does not produce good results.

SEED COLLECTION AND STORAGE

- Ripe fruits should be collected from the trees
- Fruits should never be collected from the ground as the seed in such fruits is generally insect attacked
- The fruits are heaped in the shade, rubbed and washed in water to separate out the seed which is dried in sun for a few days before storage
- The fruits may be pressed in a cloth to extract the juice and the pulp is then dried in sun, rubbed by hand and winnowed to remove the seed
- About 430-460 seeds weigh one gram.
- Seed stored in gunny bags is reported to lose vitality completely after one year's storage.
- Carefully prepared seed can be stored in sealed tins in which it keeps well.
- The seed stratified in layers of fine dry sand or ash keeps well for over two years.

NURSERY TECHNIQUES

- Sowing in the nursery is done in May-June, soon after seed collection.
- Sowing is done in lines about 20 cm apart.
- Stratification in moist sand at about 5^0C temperature for about 30-90 days is reported to improve germination.
- Soaking of the seed in cold water for about a week is also reported to hasten and ensure uniform germination.
- Pre-sowing treatment of the seed with kerosene oil is also recommended to protect it from being carried away by ants.
- One bottle of kerosene oil is sufficient to treat about 37 kg seed.

Plate 14.2 Clonal nursery of *Morus alba*

- The seed is mixed with ash or sawdust to ensure uniform sowing.
- It is covered only lightly with fine soil.
- Germination commences in about a week and may be complete in another 10 days
- The seedlings are transplanted when about 10 cm tall at a spacing of about 60 x 60 cm.
- Transplanting may be done in winter.
- For the production of stumps, the seedlings may be retained in the nursery for one or two years depending on their growth rate.
- About 2 cm collar diameter is considered to be the most suitable size for stumps.

PLANTING TECHNIQUE

- Out of the two common methods namely, planting out of entire plants and stump planting, the latter ensures higher success and is preferred.
- Stumps are prepared out of one or two years old seedlings ensuring that their collar diameter is normally not less than 1 cm.
- Stumps of about 1.5-2 cm collar diameter perform better.
- Stumps with about 22 cm root and 8 cm shoot are prepared with a sharp tool so that these do not spilt during preparation.
- These are wrapped in moist gunny bags during transport.

- Planting is done either in crow bar holes or in 30 cm^3 pits.
- *Morus alba* can be raised by planting branch cuttings also. This method is however, not employed for raising plantations and is employed to multiply clonal material of good varieties.
- The spacing depends upon the objectives of raising the plantations.
- Close spacing may suffice if the trees are to be pollarded for leaf production.
- Wider spacing of 4 x 4 m or 5 x 5 m may be necessary if timber and leaf production are to be combined.

ECONOMIC IMPORTANCE

- Wood is in chief demand for sports industry especially used for hockey sticks, tennis and badminton rackets and cricket bats etc.
- Used for boat-building, house construction, furniture
- It is good fuelwood having calorific value of sapwood and heartwood 4658 and 5003 kcal/kg respectively.
- The leaf fodder of mulberry is of good quality
- The leaves are used for silk worm rearing

Plate 14.3 *Grewia optiva* tree

Botanical Name: *Grewia optiva* Drumm.

Common Name: Beul, Dhaman

Family : Tiliaceae

Description

- It is a very popular tree of the farmers of the sub-Himalayan tract for its fodder and fibres.
- A full grown tree is moderate sized with spreading crown, reaching a height up to 12 m with a clear bole of 3-4 m and a girth of about 80 cm.
- Bark is smooth and whitish-grey.
- Flowers 1-8, solitary and axillary, petals yellow or white.
- The fruit is a fleshy drupe, 2-4 lobed, olive green when immature and black when ripe, and edible.

Distribution:

- It is distributed from the foothills of the Western Himalayas from Jammu and Kashmir to Nepal up to 2000 m elevation.
- It is not a common forest tree and is generally grown on field boundaries or terraces raised by the hill farmers.

Site factors

- It is a tree of sub-tropical climate.
- In its natural habitat, the maximum shade temperature seldom exceeds 38^{o}C and the minimum rarely drops below -2^{o}C.
- Tree is hardy and grows on a variety of soils. Sandy loam soil with adequate moisture supply supports good growth.

Phenology

- Leaf-fall - March-April
- Leaf renewal - April-May
- Flowering - April-May
- Fruiting - June-July
- Fruit ripe - October-November

Silvicultural characteristics

- Strong light demander
- Require complete over head light
- Seedling suppressed by weed
- It is frost hardy tree
- Young seedling dieback due to severe frost
- It coppice very well
- Susceptible to fire and browsing

Natural Regeneration

- Natural regeneration occurred sporadically
- Seed coat is hard
- Germination take place after the seed get soaked for more than 12 hours
- Long tap root is formed during the first year which is longer than the shoot length

Artificial regeneration

Grewia optiva can be propagated by seeds, transplanting of nursery raised seedings, by cutting or planting stumps.

Seed collection and storage

- The fleshy drupes are edible,
- A substantial quantity of fruit crop is devoured by the birds, if seed collection is delayed.
- The fruits are not borne on the current year's shoot, tree lopped completely do not bear fruits.
- Therefore, trees reserved for seed production should either not be lopped at all or if necessary only partially.
- The fruits are rubbed and washed in water to separate out the seeds.
- Each fruit contains 2-4 seeds;
- There are about 12,000 to 15,000 seeds per Kg.
- The seeds have a hard testa and can be stored well for at least a year without any appreciable drop in vitality.

Nursery Technique:

- Pre-treatment of seed is necessary as seed coat is hard.
- Sowing should not be done on raised beds as moisture needed for germination.
- The dibbling method of sowing with twice a day irrigation proved to be the best in germination percent.
- The seed is sown in March-April, about 2 cm deep in lines 15 cm apart
- Watering is done regularly till germination is over. Germination starts in about 10 days and takes a month to complete.
- Sowing in March results in prolonged and scattered germination with heterogeneous stock.
- The seedlings are spaced about 10 cm apart in lines.
- The growth of the seedlings is fairly fast and they attain a plantable height of 30 cm or more by July.

Planting Out:

- Planting is done at the onset of monsoon, late planting generally fails.

- Seedlings uprooted from the nursery with balls of earth are wrapped in moist gunny bags and transported safely.
- Planting is done in 30 cm^3 pits at a spacing of 4x4 m for block planting and 4-5 m for single row planting along the field bunds. For stump planting 15 month aged seedlings are used.

Vegetative Propagation:

- It can be successfully propagated by cuttings, under intermittent mist.
- Soaking the cutting base for 20 hrs in 100 mg/litre IAA gave a maximum rooting of 77.5 % in June.
- The technique used for mass multiplication of cuttings for plantation and seed orchard establishment.
- It can also be propagated by air layering.

ECONOMIC IMPORTANCE

Small timber:

✓ The wood is white, heavy, hard, elastic, strong and fine-textured.

✓ It is used for oar-shafts, axe-handles, shoulder poles, cat frames, bows and several other purposes, where strength and elasticity is required.

✓ The wood is difficult to saw when green but also difficult to work by hand after seasoning. It is reported to be suitable for paper-making.

Fibres:

✓ The bark yields a fibre of inferior quality used for cordage.

✓ The elastic branches are used for making baskets.

Fuel-wood:

✓ Though used as a fuel wood, not liked very much because of the foul foetid smell it emits on burning.

LECTURE-15

"LEARNING OBJECTIVE: ECONOMICS OF CULTIVATION-NURSERY AND PLANTING OF *Delbergia sissoo* Roxb."

Scientific Name	**:**	*Dalbergia sissoo* **Roxb**.
Common Name	**:**	Shisham, Sissu
Family	**:**	Leguminosae
Sub Family	**:**	Papilionoideae

Plate 15.1(a). *Delbergia sissoo Roxb.* Tree pattern

Plate 15.1(b). Shisham bark & leaf

Description:

- It is a large deciduous tree with light crown having thick, rough, grey bark with shallow broad longitudinal fissures exfoliating in irregular woody strips and scales.
- It attains a height up to 30 m and a girth of 2.4 m.

Distribution:

- The spp. occurs throughout the sub-Himalayan tract and outer Himalayan valleys from the Indus to Assam; usually upto 900 m, but occasionally ascending upto 1500 m.

- Grow gregariously on alluvial soil along stream bank, beds and islands, and on freshly exposed soil along roads and landscapes along with Khair.

Climate

It grows from tropical to sub tropical climate.

- Temperature - Maximum 40°C to 50°C, Minimum 4°C
- Rainfall - 760 mm to 4600 mm
- Altitude - Upto 1500 m.

Phenology

- Leaf-fall - November to December
- Leaf renewal - January-February
- Flowering - March/April
- Fruiting - May – July
- Fruit ripe - November-December
- Seed collection - November-December
- Seed viability - 12 - 18 months.
- Seed weight - 530 / gm.
- Germination - 80 per cent.

Silvicultural characters

- *Delbergia sissoo* is a strong light demander
- It is very frost and drought hardy spp.
- It is wind firm in nature and sensitive to fire and browsing

Regeneration

NATURAL-

- ✓ Seeds germinated during rainy season give good survival,
- ✓ Seeds regenerate on newly exposed soil, along water channel, riverine tract.

ARTIFICIAL-

- ✓ It is one of the easiest species to propagate through almost all the common methods viz. direct sowing, entire transplanting, stump planting.

Seed collection and storage:

- The seeds are plentiful every year, and keep viability for one year.
- Fertile seeds are produced at the age of 3-4 years, but it is advisable to collect seeds from the middle aged vigorously growing trees having straight and clean boles; on an average a medium sized tree produces 12-15 kg pods (4-5 kg clean seed).
- Time of collection varies from December to mid-February in Assam; West Bengal, Punjab and from November to March in Bihar and Orissa.
- The seed can be collected by ascending the tree or beating off with sticks.
- The pods are dried in the sun for 3-4 days and stored after removing dead leaves, foreign matter, etc.

Germination capacity and plant percent:

- Germination capacity and plant percent in *Delbergia sissoo* are about 90 and 45 per cent respectively.

Nursery technique

- Soaked seeds germinate after 7 to 15 days.
- Pricking by end of first season (18-20 cm height). 56 kg seeds are sufficient for one ha area.

Planting technique:

- **Direct sowing:**

✓ Direct sowing is the easiest method to raise shisham plantations; in fact, most of the seeds are sown in lines at the break of rains.

✓ Distance between lines varying from 3 to 4m.

- **Entire planting:**

✓ The planting of entire seedlings being much more laborious and costly, is adopted only in special cases such as arid areas, areas infested with tall grasses, wet sides or along the roadsides.

✓ Planting is generally done when the summer rains have properly set in, while the pits may be dug sometimes earlier.

- **Stump planting:**

- ✓ Stump planting has clear advantages over either entire planting or direct sowing.
- ✓ Cost of stump planting is low; planting period is extendable from July to September.
- ✓ The season of stump planting would depend upon the local rainfall and availability of artificial irrigation.
- ✓ Best time for planting is the rainy season.
- ✓ Stumps are spaced 1.8 m apart in lines on trenches which are 3 m apart from row to row.

Economic importance

- Furniture and house construction
- Fuel and charcoal
- Leaf fodder
- Anti-erosion works

Appendix
Model - 1

Agro-Forestry Project Profile

A-C Zone : Gujarat Plains and Hill Region
Situation : Rainfed

Tree-CropsCombination : Agrisilviculture
Tree : *Dalbergia Sissoo* (Sheesham)
Crop : Castor

Input / Output Analysis

Amount in Rupee

Year	Expenses Per Ha			Benefits Per Ha			Net Benefit Pe Ha
	Tree	Crop	Total	Tree	Crop	Total	
1	7000	240	7240	0	2000	2000	-5240
2	0	240	240	0	2000	2000	1760
3	0	240	240	0	2000	2000	1760
4	0	216	216	0	1800	1800	1584
5	0	192	192	0	1600	1600	1408
6	0	168	168	0	1400	1400	1232
7	0	144	144	0	1200	1200	1056
8	0	120	120	0	1000	1000	880
9	0	96	96	0	800	800	704
10	0	72	72	0	600	600	528
11	0	48	48	0	400	400	352
12	0	24	24	0	200	200	176
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
20	0	0	0	112000	0	112000	112000
Net Present Value @ 15% DF			**7,080**			**15,117**	**8,037**

Assumptions :

Tree : Dalbergia Sisoo : Rotation 20 (1)

1.No. of trees/ha =280

2. Income per tree = Rs.400

3. Expenses per tree =Rs.25(in the first year)

Crop : Castor

1. Yield per ha.= 250 kg.
2. Sale price per kg. = Rs.8
3. Expenses per ha. = Rs.240

Analysis :

Benefit Cost Ratio at 15% Discount Factor : 2.14

Net Present Value in Rs. at 15% Discount Factor : 8,037

IRR : 30%

Investment :

Year 1 - **Rs.7240**

Note : 1. There is 10% reduction in area under crops due to shade effectof tree from the fourth year onwards.

2. Investment proposed includes expenses on trees and crop in the first year.

LECTURE-16

"LEARNING OBJECTIVE: ECONOMICS OF CULTIVATION-NURSERY AND PLANTING OF *Eucalyptus tereticornis Sm.* AND *Tectona grandis* L."

Plate 16.1 *Eucalyptus tereticornis Sm.*

Botanical Name: *Eucalyptus tereticornis* Sm.

Common Name: Eucalyptus, Safeda, Nilgiri

Family : Myrtaceae

Description

- It is a tall tree upto 40m high
- Bole is straight and clean with whitish mottled bark
- The crown is open
- Juvenile leaves opposite
- Adult leaves alternate
- Inflorescence axillary usually seven flower umbel

Distribution

- In India Eucalyptus is second most widely plated species after teak
- It is distributed/planted all over India except North-eastern states
- In is planted both in the forest and outside in agricultural lands, wasteland, roadsides etc.

Site factor

Climate

Temperature - Maximum 22°C -32°C, Minimum 2°C-12°C

Rainfall - Upto 1500 mm

Altitude - Upto 1700 m.

Soil

- It can be grown in wide variety of soil such as recent alluvial soil, laterite soils, sand dunes, ravine, murum soil and sandy loam soils etc.
- It can be grown in soils having pH more than 10 but growth is poor when pH exceeds 8.5.

Phenology

- It is evergreen species
- Flowering - Twice a year 1st in May-June 2nd in October-November
- High number of fertile seeds was set in first flowering
- Seed collection - July-August

Silvicultural characters

- String light demander
- Susceptible to frost because of thin bark and essential oil in the plant tissues
- Good coppice
- It is a wind firm in nature
- Damaged by termites

Natural Regeneration

- Very poor due to destruction of seeds by ants
- Young seedlings smothered by leaf collar
- Leaves are toxic and contain germination inhibitor

Artificial Regeneration

Seed collection and storage:

- Seeds should be collected from 10year old trees. Although fertile seed is available from young tree
- In a year two collection 1st - February-March and 2nd – October-November
- Capsules should be dries in shade for one day
- Gently shaken to clean the shells
- Dry and stored in a tins at cool dry places
- 3,67,400 seeds weigh one Kg

Nursery techniques:

- Seed should be sown in raised nursery bed in the month of October-November or February-March
- Soil should be sterilized with Aldrex or BHC against termites
- Seed should be sown 20gm/m^2 of bed in lines 10cm apart and 2.5mm deep
- Germination takes place within 5-15 days of sowing
- 60-75 seedlings are obtained from one gram of seeds
- Seedlings are pricked out when they attain a height of 4-8cm
- Pricking of seedling should be done in to polythene bag
- Polythene bags initially should be placed in shade for few days and then shifted in the open in sunken beds
- The seedlings are hand watered for some time and later the beds may be irrigated.

Planting out:

- The area to be planted is clear felled ploughing and properly soil working should be done
- In Terai areas of UP for the first year only cash crops are raised and plantings is done in the 2nd year
- Pit size should be 45cm^3 or 30cm^3
- For saline and alkaline soils large pit of 60cm^3 with soil replacement with good soil are dug out at wider spacing
- Planting is done in July in areas subject to South-West Monsoon
- October-November in areas of North-East Monsoon
- Container/bag should be removed at the time of planting
- Watering and fertilizer application should be done in poor soils
- Casualties are beaten up immediately after planting in the first year
- In arid areas 3-4 watering in the first year produce good stock

Spacing

- Spacing depends upon the objective of plantation
- Spacing varies 1.8m × 1.8m – 3m × 3m
- For firewood/fuelwood

  1m × 1m or 1.5m × 1.5m
- For pulpwood/poles

  2m × 2m or 3m × 2m
- For saw log

  3m × 3m
- For Windbreaks and shelterbelts

  1.5m × 1.5m or 2m × 1m

Vegetative propagation

- Clonal propagation has been attempted by means of Grafting, budding, air layering and soft wood cutting
- Propagules should be treated by IBA 10000ppm
- The selected plus tree are cut at about 12cm height from the ground level
- The coppice shoot are harvested between 45 days and 55 days after the tree has been cut
- The cut shoot are placed in a bucket of water transplanted to the nursery
- The length of cuttings vary from 10-15cm
- The base of the cuttings should be treated with 200ppm solution of Benlate Fungicide for 15-30minutes
- The base up to 2cm is treated with 6000ppm IBA diluted with talc powder
- The cuttings are planted in polythene tubes
- The growing media is vermiculite
- Cutting develop good root system within 5-6 weeks

Tending operations

- Like weeding, fertilization thinning etc. Should be done time to time

Economic importance

(i) Pulp and fuel

(ii) Pole for general purposes

(iii) Leaves for oil

Plate 16.2 *Tectona grandis* L. tree

Botanical Name: *Tectona grandis* L.

Common Name: Teak, Sagwan

Family : Verbanaceae

Description

- Large deciduous tree up to 30 m high and 100 cm or more dbh
- Long straight cylindrical bole up to 2/3 of the height of tree.
- Deep tap root system
- Bark pale brown, grey, striate, fibrous, peeling off in thin strips
- Branch lets are quadrangular and channelled

Distribution

- Indigenous in both peninsulas of India, in North-Eastern drier part of Java and other islands of Indian Archipelago
- The Nilambur in Kerala, manmade teak forest are known to foresters throughout world.
- Natural habitat is between 10°N and 25°N on Indian subcontinent, in South-East Aisa especially in India, Burma, Thailand, Laos, Combodia, Vitenam and Indonesia.
- It does not occur naturally in Malaysia

Site factors

Climate

- Teak naturally occurs only in monsoon climate
- Temperature - Maximum 48°C, Minimum 2°C
- Rainfall - 700mm to 2200 mm
- Altitude - 600m to 1200 msl.

Soil

- It grows on variety of geological formations notably trap, limestone, granite, gneiss, mica schist, sandstone, quartzite and clay
- Well drained, well ventilated soils with high oxygen content are best
- Absent in soil having pH < 6.0pH and >8.5pH

Phenology

- Leaf-fall - Dry area- November to January
  - Wet area- March
- Leaf renewal - May
- Flowering - June to September
- Fruiting - November to January
- Seed collection - January/February
- Seed viability - more than 1 year
- Seed weight - 125 to 176 per 100 gm.
- Germination - 60 to 80 per cent.

Silvicultural characters

- Strong light demander
- Frost tender
- Drought and wind sensitive
- Fire resistant
- Not browsed
- Good coppice

Plate 16.3 *Tectona grandis L.* fruits

Regeneration

Natural-

- Seeds abundantly
- Requires warmth and light for germination
- In cool shady places the seeds may lie dormant for years
- Establishment of seedlings largely depends on light
- Frost sensitive nature hence seedlings are killed by frost
- Light burning is beneficial
- Weed growth and ground vegetation is obstacles
- Especially *Lantana camera* discourages its regeneration

Artificial-

- First ever plantation is carried out in Nilambur in 1842 under Conolly.
- Seeds, coppice shoots, stump etc.

Seed collection and storage

- Viable seeds obtained from the age of 5-6years
- Twenty year old plantation regenerates naturally
- Nine year old coppice raised plantation produce healthy seedlings
- Seeds should be collected underneath the trees during January-March
- Seeds cleaned and dried are collected in gunny bags and stored in dry areas
- 35 Kg seeds are required to produce stumps for one hectare area

Pre-sowing treatment

- Necessary to break dormancy of the seed
- Seed germination in the untreated seeds is totally absent or very in-significant
- Following treatments require to break dormancy of the seed
    - ✓ **Natural Weathering**

      Seeds are spread over raised platform in the middle of August during rains seeds get soaked and then with sun they get dried thus getting natural weathering
    - ✓ **Artificial weathering**

      Freshly collected seeds are put in gunny bags which are then submerged under flowing water for four days. The gunny bags are taken out and spread over in strong sun for four days. It is again submerged in water for 3-4 days following drying. It is repeated for 3-4 times until endocarp and mesocarp get easily cracked
    - ✓ **Pit method**

      Seeds are put in alternate layers of seeds and straw and daily watered for seven days then dried and stored till the time of sowing
    - ✓ **Soaking in water**

      Immersion of seeds in water for number of days has hastens germination
    - ✓ **Biological method**

      Burying the seeds for one year near the ant hill is reported to give better results
    - ✓ **Chemical treatment**

      Soaking the seed in concentrated H_2SO_4 for 20 minutes and thorough washing in running water hasten germination
    - ✓ **Scorching**

      Scorching the seeds in light running fire of leaves of grass or alternatively seed picked from plantation after a light ground leaf-fire is useful method
    - ✓ **Cowdung**

      Soaking the seeds in the mixture of cowdung and water enhance germination

Nursery technique

- Nursery beds are prepared one year in advanced of planting
- Beds of 12 m × 1.2 m size are prepared
- In moist localities raised beds are prepared while in dry localities sunken beds are helpful for germination
- Seeds are sown in the nursery bed from February-June
- 2.5-3 Kg seeds are required per bed
- About 1200-1500 seedlings are expected

Preparation of stumps

- Stumps with 1cm to 2cm diameter at collar level with about 25cm root portion and 2.5cm stem portion are most suitable

Plantation technique

Direct sowing

- It is practiced very limited scale due to heavy causality

Entire transplanting

- Dona plants are preferred in place of tree in place of pre-sprouted or normal teak stumps
- The soil in dona retains moisture for comparatively longer period and keep the plant alive
- Dona plants are 4-6 months old at time of planting or casualty replacement in July-August

Stump planting

- This is the most useful and economical method for teak plantation
- Stumps are plated in crow bar holes and generally buried up to the collar
- In Odisha and drier part of Tamil Nadu stumps are buried up to the tip
- In Madhya Pradesh in hard soil stumps are planted in 15cm diameter hole and about 30cm deep
- While planting the stumps the collar is flushed with ground level

Pre-sprouted teak stumps

- In very dry locality pre-sprouted stump planting give satisfactory results
- The stumps are planted 4-6 month in advance and put in container raised on a platform in shade and watered daily
- These stumps after sprouting are planted at the onset of monsoon
- The planting of sprouts is done with the ball of Earth intact in cylindrical holes

Polythene bag

- Planting of seedling raised in polythene bags have also been tried in such cases treated seeds are sown directly in polythene bags filled with manured soil
- The bags are watered daily and planted out when seedling attains a height of 15cm

Vegetative propagation

- Teak can be propagated by grafting, layering and rooting branch cutting
- Among the grafting method used bud grafting is preferred as it is easy, economical and more suitable for grafting on stumps
- Grafting success depends upon age of mother plant, time of grafting and method used

Economic importance

(i) Furniture and house construction

(ii) Ship and railway coach

(iii) Wood oil for decreasing durability of timbers

A-C Zone : West Coast & Ghat Region
Situation : Rainfed

Tree-Crop combination: Agrisilviculture
Tree: *Tectona grandis* (Teak)
Crop : Sweet Potato

Input / Output Analysis

Amount in Rupees

Year	Expenses Per Ha			Benefits Per Ha			Net Benefit Per Ha
	Tree	Crop	Total	Tree	Crop	Total	
1	38000	18000	56000	0	30000	30000	-26000
2	11875	18000	29875	0	30000	30000	125
3	11875	18000	29875	0	30000	30000	125
4	11875	18000	29875	0	30000	30000	125
5	11875	18000	29875	0	30000	30000	125
6	11875	18000	29875	0	30000	30000	125
7	11875	18000	29875	0	30000	30000	125
8	11875	18000	29875	0	30000	30000	125
9	11875	18000	29875	0	30000	30000	125
10	11875	18000	29875	0	30000	30000	125
11	11875	18000	29875	0	30000	30000	125
12	11875	18000	29875	0	30000	30000	125
13	11875	18000	29875	0	30000	30000	125
14	11875	18000	29875	0	30000	30000	125
15	11875	18000	29875	0	30000	30000	125
16	11875	18000	29875	0	30000	30000	125
17	11875	18000	29875	0	30000	30000	125
18	11875	18000	29875	0	30000	30000	125
19	11875	18000	29875	0	30000	30000	125
20	11875	18000	29875	3800000	30000	3830000	3800125
Net Present Value @15% DF			**209,715**			**419,961**	**210,246**

Assumptions :

Tree: Tectona grandis : Rotation 20 Years

1. No of trees per ha.= 475
2. Income per ha. = Rs.3800000 (in the 20th year)
3. Expenses per tree=Yr 1=Rs80, Yr 2 & & onwards =Rs 25

Crop : Sweet Potato

1. Yield per ha=10000 kg.
2. Sale price per kg. = Rs 3
3. Expenses per ha =Rs.18000

Analysis :

Benefit Cost Ratio @ 15% DF = 2.00

Net Present Value @ 15% DF = 210,246

IRR = 30%

Investment:

Year 1 = Rs 56000

Year 2 to 20 = Rs 225625

Total = **Rs. 281625**

Note : Investment proposed includes expenses on trees for 20 years and expenses on crop for the first year.

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Source: Report of the task force on greening India for livelihood security and sustainable development. Planning Commission. Government of India. July-2001

LECTURE-17

"LEARNING OBJECTIVE: ECONOMICS OF CULTIVATION-NURSERY AND PLANTING OF *Quercus leucotricophora* A. AND *Dendrocalamus hamiltonii* Nees."

Plate 17.1 Flowering of Ban oak

Plate 17.2 Nuts of Ban oak

Botanical Name: *Quercus leucotrihophora* A.

Common Name: Ban oak

Family : Fagaceae

Description

- It is moderate sized to large evergreen tree with almost rounded crown
- It attains a height of 20m and diameter of 60cm,
- The bole is irregular and short.
- The bark is greyish brown, rough with cracks and fissures exfoliating in irregular oblong.
- Young leaves are pinkish and woolly all over mature dark green and glabrous above.
- Male spikes slender, drooping 5-10cm long
- Male flower axillary
- Acorn generally solitary usually born on current year shoot
- Ripe nuts ovoid conical brown when ripe 2.5cm long

Distribution

- Occurs in the moist and cooler aspects in Western Himalayas between altitudes 800m to 2300m on southern aspects,
- The limits are lower by 200 to 300 m on the northern aspects.
- In Kangra valley, it is reported to occur even at 600m elevation.
- It is principal species of ban oak forest of lower West Himalayan Temperate Forest
- It is associated with *Quercus dilatata, Cedrus deodara, Pinus wallichiana* however, at lower elevation with *Pinus roxburghi*, *Quercus glauca* and *Quercus lanuginose.*

Site Factors

Climate

- It is a tree of temperate climate
- In its natural zone maximum shade temperature never exceeds 35°C while in lower limit in subtropical zone temperature may reach 38°C
- During January most of the area in its upper limit of its distribution receives snowfall but it make small part of precipitation, the major part is received in the form of rainfall during June to September.
- The total annual rainfall varies from 1000-1800mm

Soil

- It grows on wide variety of geological formations and soils such as shale, gneiss, schist, quartzite and limestone rocks and mostly sandy or clayey loam soils.
- It grows best on cool Northern aspect with deep moist shale soils

Phenology

- It is an evergreen tree, old leaves falls after the appearance of new leaves and thus trees are never leafless
- New leaves appear in the month of March-April
- Shading of old leaves and appearance of new leaves first starts at lower elevation of its occurrence
- Male catkins and female spikes appear on new shoots in April-May
- The fruit ripens in December-January after 19-21 month of flowering

- Seedings starts comparatively at early age tree of 26 years and coppice of ten year age have been reported bearing fruit

Silvicultural characters

- It is moderate light demander,
- It can withstand fair amount of shade in early age,
- Trees growing under shade develop restricted crown while those grown in the open have well developed crown
- Tree are resistant to ordinary frost but severe frost kills seedling and sapling
- Seedlings are sensitive to drought particular in first two years,
- Due to massive root system tress are wind firm,
- Trees are susceptible to fire
- It coppice well in young age and it declines with age.

Regeneration

Natural –

- ✓ With favourable conditions germination takes place after early showers.
- ✓ Germination takes place in June to July after receiving of first showers.
- ✓ Germination may takes in heavy or moderate shade but seeds fail to germinate in places expose to direct sun.
- ✓ Drought is the most adverse factor causing seedling mortality.
- ✓ The growth of seedling under natural condition is slow and they attains height of 10cm in first season and about 25cm in four years.
- ✓ Seedling develops a long tap root and the growth of root is generally more than that of shoot during the first few years

Artificial –

- ✓ It can be raised easily through direct sowing, planting out of nursery raised seedlings.
- ✓ Air layering is also possible and with application of auxins encourages rooting.
- ✓ On dry slope transplanting ensures more survival.

Seed collection and storage

- Good seed years are frequent

- Acorns are collected in December to January preferably from tress
- Acorns are dried under shade only and stored in cool place protected against insect-pest
- The seeds can be stored for one year
- About 400-800 acorns weigh one Kg
- Storage of acorns at low temperature and high humidity is advocated

Direct sowing

- Ban oak can be successfully raised by direct sowing either dibbling the seed in cultivated line or patches
- The seeds are sown about 2cm deep during December to January or before the onset of the rains
- About 5 Kg of acorns are sufficient for one hectare area
- Fresh seed registered 60-70% germination
- Sown area should be protected against grazing and fire

Nursery technique

- Seeds are sown in February-March in well manure and raised beds.
- Seeds are sown in lines about 20cm and seeds are spaced at 5cm in the lines at a depth of 2cm.
- Deep sowing delays the germination and also reduces germination percentage.
- Beds should be prepared under light shade, not under direct sunlight.
- Germination starts in about 10-12 days and takes to 4-5 days to complete.
- Regular weeding also required.
- Seedlings are spaced at 10cm in lines in the second rainy season after pruning the roots
- The growth of seedlings is fast and they attains a height of 50-60cm in two year

Planting technique

- Seedlings of about 15-20cm height are suitable for planting out as taller seedlings are difficult to handle due to their massive roots.
- Rainy season gives better results than winter planting.

- Planting is preferably completed by July as later planting brings out poor survival.

Tending

- Species is slow growing and it needs weeding and cleaning for several years.
- Planting should be guarded against cattle browsing and forest fires.
- Improvement fellings and thinning in natural seedlings is to be done at 10years intervals.

Economic importance

- The major use of ban oak is for fuelwood and charcoal making, for which it is in great demand.
- Calorific value of fuelwood is 4600 k cal/Kg.
- Charcoal conversion factor is about 16-20%.
- Tree is lopped for fodder and a mature tree can yield 20-25Kg leaves annually.

Plate 17.3 *Dendrocalamus hamiltonii* Nees.

Botanical Name	**:**	*Dendrocalamus hamiltonii* Nees.
Common Name	**:**	Magar bans
Family	**:**	Poaceae/Graminae
Sub Family	**:**	Bambusoideae

Description

- It is a large bamboo, culms growing at an angle
- Culm are greyish white when young and dull green when old
- About 12-25m height and 10-19cm diameter
- Internodes are 30-50cm long
- Culm sheath is glabrous, rough with brown hairs on outer side

Distribution

- Found throughout in North-West Himalayas, Sikkim, Bhutan, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura
- Cultivated in Himachal Pradesh between altitude 350-1400 m at Chamba, Mandi and Bilaspur

Site factor

Climate

- Rainfall varies from 750-5000mm in its natural range
- Temperature maximum 46°C and minimum -5°C

Soil

- It grows on wide variety of soils having good drainage
- Sandy loam soils underlain by boulders are most suitable
- It is rarely found on heavy soils such as clay or black cotton soils

Phenology

- Flower sporadically or gregariously
- New culms arise from buds on the rhizome during August
- New culms attain their full length by November-December

Natural regeneration

- Reproduction of bamboos is through rhizomes
- Rhizome is underground portion of the stem, closely similar in structure to the above ground portion of the stem i.e. culms and branches
- The buds on rhizomes, which usually develop are generally one year old
- It is affected by careless fellings, non observance of cutting and grazing rules are the other causes which lead to congestion, reduce the yield as well as deteriorate the quality of bamboos

Artificial regeneration

Rhizome planting

- Separated out rhizomes can be planted in the rainy season
- Traditional method of planting is by offsets at the onset of rainy season in June-July and about 50% survival rate is expected
- Culm is cut at a height of 1-1.5 m just above the joint and rhizome severed at the desired oldest narrow point
- A pit of 60 cm^3 and spacing of 6 m × 6 m and 7 m × 7 m is desirable
- The established plants yield culms of exploitable size in 4-5years

Single node cutting

- One node cuttings, each with major length of its basal and minor of distal internode are taken from the under one year old culms and planted in March
- Before planting the cuttings, their branches are trimmed above third to fifth node beyond the condensed basal portion
- The cuttings are planted horizontally with the branch or bud upward, 10-15 cm deep in rows and covered with soil having well decomposed farm yard manure

Mass production

- A new technology for mass production of seedling developed by the FRI
- Sowing seed in July in the germination trays, when the seedlings reach 3-4 leave stage they are planted in polybags containing equal proportion of soil, sand and FYM
- At the age of eight month seedlings are removed from polybags in April
- Proliferated tillers of these seedlings are separated by cutting rhizome to act as propagules
- Each propagules consists of a tiller along with rhizome and roots

Economic importance

- It is used for rafters, house posts, ladders, tent poles, shafts of tongas, scaffoldings etc.
- Shoots are used as vegetable and pickles
- Important raw material for paper mills

LECTURE-18

"LEARNING OBJECTIVE: ECONOMICS OF CULTIVATION-NURSERY AND PLANTING OF *Tamarindus indica* L. AND *Azadirachata indica.* A."

Plate 18.1 *Tamarindus indica* L.

Botanical Name: *Tamarindus indica* L.

Common Name: Emli, Tamarind

Family : Leguminosae (Caesalpiniodeae)

Description

- It is a large evergreen tree attaining a height up to 15m
- Spreading crown 9 to 12m in diameter with numerous branches and twigs.
- The trunk is short, the lower branches are borne almost horizontal.
- Bark is moderately thick and dark grey with numerous longitudinal fissures and horizontal cracks.
- Two varieties has been identified East Indian variety with long pods, 6-12 seeded
- West Indian variety with shorter pods, 1-4 seeded

Distribution

- One of the most common tree of Tropical India,
- It is believed to be indigenous to Tropical Africa probably introduced long back to India by Arabs.
- It is not tree of forest but is cultivated throughout country except Himalayan region and arid western zone.

Site factor

Climate

- Temperature - Maximum 35°-46°C Minimum 0°-17.5°C
- Rainfall - 750-1900mm
- Altitude - up to 1000m

Soil

- It is non-exacting type tree
- It tolerates slightly saline and alkaline soils
- Best growth is found on deep loamy or alluvial soils with adequate supply of moisture

Phenology

- Leaf-fall - April-May
- Leaf renewal - March-April
- Flowering - April-June
- Fruiting - March-April
- Seed collection - March- April
- Seed weight - 1800-2000 seeds per Kg
- Germination per cent - 75%

Silvicultural characters

- Strong light demander can't grow under shade,
- Frost tender,
- Resistant to drought,

- Produce root suckers and coppice well
- Deep rooted and wind firm in nature
- Not fire hardy but considered best tree for planting along fire lines in Karnataka.

Regeneration

Natural –

- It is not adequate in any circumstances.
- Scattered seeds may germinate especially in abandoned areas, ruins etc.
- Weeds retard the growth of the seedlings whereas weeding greatly favours growth.
- The seedlings may attain a height of 0.6m or more in the first season and 1.20 m or more in the second season if they are regularly weeded and watered.

Artificial –

- It can be raised easily through direct sowing, planting out of entire plants or stump planting or poly bag container plants.

Seed collection and storage

- Plant begins to yield seed when about 8-10 years of age
- Ripe pods are collected in the month of March-April
- Seed is separated from edible pulp by washing with water then dried and stored
- Fully grown tree produce 2 quintal of fruits per season
- Individual pods contains 3-10 seeds

Nursery technique

- Seeds sown in March-April in irrigated nursery in lines about 20-25cm apart.
- No pre-treatment of the seed is necessary.
- Germination starts in about a week and take about a month to complete
- Seedlings attain plantable size by the July when they are about 3-4 months old and attain a height of 30-40cm.

Direct Sowing

- It is done in lines or patches.
- Depth of sowing is about 1.5cm.

- The lines are spaced at 4-5 m apart and the seeds are sown 10cm apart.
- About 20 kg of seed is requires to sow one hectare area.
- It gives 80% survival against transplants 60%.

Planting technique

- Planting is done at the commencement of rainy season during July-August.
- Seedlings were irrigated with 2 litres of water while planting.
- The pit size of $30cm^3$ is recommended for planting
- The plants should be protected through fencing

Stump planting

- It is carried out in 30 cm^3 pits as soon as rain break.
- It gives 42% survival.

Vegetative propagation

- It is done with soft terminal cuttings.
- The cuttings are prepared with current year's shoots and it is collected with new leaves flush early in the morning in turgid condition.
- Cuttings are treated with 1000ppm IBA in 50% Isopropyl alcohol as quick dip for second then transfer to polypropylene tubets

Economic importance

- The chief value of this tree lies in its fruits which are used for various types of food preparations and sherbets.
- The wood is used for carving.
- It makes an ideal avenue tree by virtue of its shade, ornamental flowers and longevity (200years or more).

Plate 18.2 *Azadirachta indica* A.

Botanical Name: *Azadirachta indica* A.

Common Name: Neem

Family : Meliaceae

Description

- It is versatile, hardy Indian tree of great religious, medicinal and ornamental importance.
- It is a medium to large sized, handsome tree with rounded crown of bright green dense foliage, a stout, strong and glabrous branches.
- The bark on young trees is smooth, soft, moderately thick.

Distribution

- It grows throughout the greater parts of India, more especially in the drier parts of the country.
- It is absent in areas with excessive cold and as such dose not grow in Himalaya above 1000m elevation.
- The species has been used to afforest drier tracts, ravines and refractory soils in the states of Gujarat, Rajasthan, Punjab, Haryana, Uttar Pradesh, Bihar, Orissa, Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. It is also planted in Assam and Andaman islands also.

Climate

Temperature - Maximum 40°-45°C Minimum 0°-15°C

Rainfall - 450-1125 mm

Soil

- It grows well on a wide variety of deep or shallow soils ranging from sandy soils in Rajasthan to clayey soils in Maharashtra,
- Does not survive on water-logged, highly saline or deep dry sand.
- Best growth is reported from black cotton soils
- It is salt tolerant species and suitable for afforesting saline and alkaline soils

Phenology

- It is semi-evergreen tree
- Leaf-fall - February-March
- Leaf renewal - March-April
- Flowering - April-May
- Fruiting - June-August
- Starts fruiting at the age of 5year but economic yield is obtained at the age of 10-12 year
- Medium size tree produce 35-37Kg fruits
- About 3300-4500 seeds weigh one Kg
- Seed collection - June-July
- Seed weight - 9-10 seeds per gm
- Seed viability - 6-8 weeks, Reduces rapidly after 2 weeks
- Germination per cent - Fresh seeds upto 86%

Silvicultural characters

- Strong light demander,
- Tolerates fairly heavy shade in early years,
- Susceptible to fire and browsing damage,

- Seedling and saplings are very sensitive to frost
- Seedlings are intolerant of water logging conditions
- It can withstand drought better than excessive rainfall
- It coppices well and produce root suckers in dry locality

Regeneration

Natural –

- It is seldom found growing gregariously,
- It regenerates naturally by seeds, coppice and root suckers
- Fruit ripening coincides with rainy season; fallen fruits germinate within a fortnight giving a thicket of seedlings under mature tree.
- Germination is epigeal
- Mature tree comparatively have short tap root and number of horizontally growing lateral roots

Artificial –

- It can be raised easily through direct sowing, planting out of entire plants or stump planting

Seed collection and storage

- Fruiting starts early in south Indian and late in North India
- Seeds are preferably collected June-July or some time seeds swept from the floor as soon as they fall down
- Seed do not require any pre-sowing treatment
- De-pulping and cleaning the seed considerably improve germination percentage

Nursery technique

- Sowing in raised nursery beds is done in June in drills 15cm apart;
- The seeds being sown 2.5cm apart in the lines.
- They should be lightly covered with soil since the emerging radicles are eaten by rodents.
- Depth of sowing is to 2.5cm.

- Seed can be sown in poly bags (22cm×9cm) and later transplanted to 30cm×16cm size poly bags.
- Pricking out of seedlings or wilding is done at three leaves stage into polythene bags.

Direct Sowing

- It is done by dibbling in bushes, broadcast sowing, sowing in lines or patches, in trenches, sunken beds or circular saucers etc.
- Especially sowing in lines or patches has been employed under taungya system.

Planting technique

- One year old seedlings are considered the best over either two years or below one year.
- Planting should be done in July-August during rainy period and stopped in the non-rainy days
- Winter planting is unsuitable for neem.
- Cleaning around the pits should be done at the time of planting.

Stump planting

- It is carried out in 30 cm^3 pits as soon as rain break.
- Stumps are usually prepared from two year old seedlings,
- One year old seedlings of fertilized nurseries can also be used.

Vegetative propagation

- It is propagated by air-layering or by rooting stem cuttings and root cuttings.
- Successful air-layering was achieved by treatment with 0.1 per cent Indole-butyric acid or naphthalene acetic acid.

Economic importance: Almost every part of neem tree is useful from its roots, trunk, bark, leaves, flowers, fruits and seeds in day to day life.

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