A Theory Notes
on

Course No. FRST-121 (1+1)

Title: INTRODUCTION TO FORESTRY

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SECOND SEMESTER B.Sc. (Hons.) Agriculture

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Chapter-1

Introduction to Forest in India

Total geographical area of India is 32, 80,500 sq. km (328.8M ha)

Total forest area 7, 50,500.00 sq. km (75.06 M ha)

Agricultural area is about 46.4%

The second National Forest Policy was enunciated (decided) in 1952 as per which 33.33% of land should be under forest for proper ecological balance. In hills 60% area should be covered under tree cover. During last tow decades 2 million ha forest was diverted for non-forest purpose, Agro-industry, power and irrigation projects, housing etc. **Government has enacted the Forest Conservation Act. 1980** to ensure that no reserve forest can be diverted to any other type of forest and that no forest and that no forest land can be used for any non forest purpose.

Out of total area under forest, 45.6 million ha (60%) area is in use and another 14.8 million ha (20%) area potentially exploited and remaining unexploited area as on Himalayan states, North Eastern regions and Andaman Nicobar islands.

Sources of energy consumption in India are: Coal, 16.5%, Oil 10.0%, Electricity 15.7%, wood 37.6%, Cowdung 8.7% and Vegetation waste 11.5%.

Forest:

The wood is derived from the Latin word "Eairs" means "outside' Therefore forests are areas covering practically all uncultivated or untended lands covered with rather tall and dense tree growth.

Definitions and Terms used in Forestry:

1. **Forestry:** Forestry has been defined as 'the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources.
2. **Silviculture:** The terms silviculture, commonly refers only to certain aspects of theory and practice of raising forests crops. **OR** Silviculture pertains to the establishment, development, are and reproduction of forests crops.

3. **Pollarding:** This is a process in which the branch of a plant is cut off in order to produce a flush of new shoots. Pollarding is carried out at a height which is above the reach of browsing animals. It has been widely adopted on salix trees in Kashmir Valley. (Willow), *Hard-wickia binata* in A.P. (Anjan), *Grewia oppositifolia* in U.P. Hills (Silver oak type)

4. **Lopping:** It pertains to the cutting of branches or even young stems. This leads to the development of new shoots. It is carried out on Diospyros (Temburni) for bidi industry, also in number of broad leaved species for fuel and fodder and as *Quercus incana* (Indiana oak), morus etc, for rearing silkworm.
5. **Pruning:** Means the cutting of branches from the bole in order to maintain the quality of timber.
6. **Taungya system:** It was first evolved in Burma in 1850 as a mode of replanting vast teak areas. Taungya is a Burmas word. (Toung hill, ya - cultivation). This is a modified from of shifting cultivation of which the labour has permission to raise crop on the land, but, with this, they are responsible for planting, of the forest species, also for protection and well being of the plantation. After about five years or so, they are required to move to another patch of land.
7. **Coppice:** When certain plants or seedling are cut from near ground level, they produce a flush of fresh shoots. This is known as coppicing
8. **Seed orchards:** are plantations which may raised exclusively with the aim of producing seed.

    1. **Seed Production areas or seed stands:** Which are area set aside exclusively for the purpose (i) to produce seed of high quality from genetically superior trees available in the stand (ii) to concentrate seed collecting operation in a small sphere or area. The seed stands are established by removal of the inferior frees, seed orchards are plantation of genetically superior trees isolated to reduce pollination from genetically inferior once.

       Seeds orchards may be of two types: (i) Clonal: raised by grafting clones of superior trees on 2-3 year old seedlings (ii) Seedling raised from obtained from seeds of superior trees.

9. **Pricking out:** When the seedlings have to be kept in the nursery for more than a year, it must be transferred to beds, other than the seedling beds. This is known as pricking out or to transplant small seedlings individually in to nursery beds or boxes.

10. **Wind breaks:** Is a protective plantation in a certain area, against strong winds. It is usually comprised of a few rows of trees (or shrubs) spaces at 0.5 to 2.5 m apart.)

11. **Shelter belts:** is a wide zone of trees, shrubs and grasses, planted in rows, usually at right angles to the direction of the prevailing winds. Its aims are:
    a. To deflect the air current.
    b. To reduce the velocity of prevailing winds
    c. To provide general protection
    d. To protect the leeward area from the desiccating effects of hot winds.

12. **Tending:** Tending is a board terms given to operation which are carried out for the well being of forest crops, at any stage of it life, involving operation both on the crop itself and on its competing vegetation e.g. weeding, cleaning, thinning, improvement feeling etc. However, tending does not include operation concerning, regeneration such as regeneration feeling, soil working, control burning etc.
13. **Felling:** Felling comprise of removal of trees either singly or in small groups scattered all over the forest.
14. **Afforestation:** Establishing a forest by artificial means on an area on which not forest vegetation has existed for a long time in the past.
15. **Reforestation:** Re-establishing a forest, by artificial means on an area which previously bore forest vegetation, and which may have been felled or otherwise cleared in the recent past.
16. **Age crop:** The age of a regular crop corresponding to its crop diameters.
17. **Age classification:** The division of a crop according to difference in age **OR** the allotment of woods to age classes.
18. **Alpine:** Zone of vegetation where winter is server, slow fall heavy, the mean annual temperature is 450F and the mean January temperature below 300F. In India Himalayan at the altitude above 10,000 ft.
19. **Basal area:** The area of the cross section of a stem at breast height, when applied to a crop, the sum of basal areas of all the stems or the total basal areas per unit area.
20. **Bole:** The main stem of a tree.
21. **Breast height:** Almost universally adopted as the standard height for measuring the girth, diameter and a basal areas of standing trees. India 4'6" (1.37m). In U.K. and most commonwealth countries 4'.3" (1.30 m)
22. **Coupe:** A felling area, usually one of an annual series unless otherwise stated. Preferable numbered with Roman numbers as, I, II, III etc.
23. **Crown:** The upper branchy part of the tree above the bole.
24. **Dendrology:** The identification and systematic classification of trees.
25. **Reserved forests:** an area so constituted under the Indian Forest Act or other Forests law.
26. **Protected forests:** A legal terms for an area subjected to limited degrees of protection under the provision of Chapter IV of the Indian Forest Act.
27. **Unclassed forest:** Forest land owned by Government but not constituted in to a reserved, village or protected forest.
28. **Log:** The stem of a tree or a length of stem or branch after felling and trimming.
29. **Logging:** Operation comprising felling of trees, limbing, bucking and transportation of the resulting product out of the forest timber harvesting (Bucking-Act of being)
30. **Pole:** A young tree from the time when the lower branches begin to fall off to the time when rate of height growth begins to slow down and crown expansion becomes marked.
31. **Raft:** An assemblage of logs, timbers or bamboos tied together or enclosed within a boom for transport by floating.

32. **Scrub:** Inferior growth consisting chiefly of small or stunted trees and shrubs.
33. **Stand:** An aggregation of trees or other growth possessing sufficient uniformity in composition, constitution, age arrangement or condition, to be distinguished from adjacent crops and forming a silvicultural unit.
34. **Succession:** The gradual replacement of one community by another in the development of vegetation towards a climax

SILVICULTURE:

Introduction:
Silviculture pertains to the raising, development, care, reproduction and overall management of forest crops.
Definition: If has been defined variously as follows:

1. Silviculture is that branch of forestry which deals with the establishment, development, care and reproduction of stands of timber (**By Toumey and Korstain**) .
2. The terms silviculture, in English refers only to certain aspects of the theory and practices of raising of forests crops (**By Champion and Seth**).
3. The art and science of cultivated forests crops. On the other hands, silvics is the study of trees and forests and biological entities, the laws of their growth and development, and impact of environment on them. Thus, silviculture can be described to include all practical and theoretical aspects of silvics (**By Iffprt (IFR Dehradun)**

Objects of Silviculture:

Study of silviculture helps to attain the following object:

1. **To derive environmental benefits:** Soil and water conservation, control of air and noise pollution, wild life conservation, regulation of climatic condition, regulation of water cycle.
2. **Raising species of more economic value:** Industrial and economic growth through.
3. **Production of high-quality timer:** Silviculture techniques help of avoid the problem of crooked, malformed, disease or defective timber and thus help to produce goods quality timber.
4. **Production of more volume per unit area:** Unmanaged forests may be too dense or too open, less production, premature death of trees silviculture helps to solve these problems.
5. **Reduction of rotation period:** In Unmanaged forests the rotation tends to be longer.
6. **Afforestation of blank areas:** Waste lands can be used for forests
7. **Creation of plantation:** Man made forests or plantations may be created in placed of natural forests.
8. **Introduction of exotics:** Successful introduction of exotic species is possible.

9. **Employment potential:** In any plantation operation, the labour component account for 60 to 70% of the total financial input.
10. **Increase in the production of fuel and fodder:** In development countries like India it is important aspect.
11. **Forest Industries:** Resin for resin and turpentine industry, pulp wood for paper industry, industrial wood for match and timber industry, railway, etc, minor forests product based industries.

Classification of Forests

Forests can be classified on the basis of:

1. Age,
2. Method of regeneration,
3. Composition,
4. Ownership,
5. Object of Management,
6. Growing Stock.

1. Classification of Forest On the Basis of Age: Forest is classified into:

A) Even Aged Forest:

Even-aged forests, also called regular forests are those consisting of even - aged woods. Even - aged wood means trees of approximately the same age. True even - aged forests can be only man - made forests. In case of forests, which regenerate naturally, some age difference is often allowed. Differences up to 25% of the rotation are usually allowed in cases where forest is not harvested for 100 years or more.

B) Un-Even Aged Forests:

A forest is called uneven - aged or irregular when trees vary widely in age.

2. Classification of Forest On the Basis of Regeneration: Forests are identified into

A. High Forest: When regeneration is obtained from seed

B. Coppice Forest: When regeneration is through coppice or some vegetative part of the tree.

1. Natural Forest: When the regeneration is obtained naturally, the forests are called natural forests

2. Man Made Forest: When it is obtained artificially, the forests are called Man-made forests or Plantations.

3. Classification of Forest On the Basis of Composition: Forests are classified into

A. Pure Forests: Pure forests are composed almost entirely of one species, usually to the extent of not less than 50 per cent.

B. Mixed Forests: Mixed forests are defined as forest composed of trees of two or more species intermingled in the same canopy.

4. Classification of Forest On the Basis of Management: Forests are classified into

A. Protection Forests: Protection forests are those which are managed primarily for ameliorating climate, checking soil erosion and floods, conserving soil and water, regulating stream flow and increasing water yields and exerting other beneficial influences.

B. Production Forests: Production forests are those which are managed primarily for their produce.

C. Social Forests: Social forests where the produce is utilized by neighboring society.

5. Classification of Forest On the Basis of Ownership: Forests can be classified as

A. Government Forests: On the basis of Legal status, Government forests are further classified into:

a. Reserved Forests: A Reserved forest is an area with complete protection, constituted according to chapter II of the Indian Forests Act. 1927.

b. Protected Forests: A Protected forest is an area subject to limited degree of protection constituted under the provisions of chapter IV of the Indian Forest Act., 1927.

c. Village Forests: A Village forest is a state forest assigned to a village community under the provisions of chapter III of Indian Forest Act.

B. Private Forests:

C. Forests owned by Corporations, Panchayats, Societies and other Agencies.

6. Classification of Forest On the Basis of Growing Stock: A forest can be classified into

A. Normal Forest: A Normal forest is an ideal forest with regard to growing stock, age class distribution and increment and from which the annual or periodic removal of produce equals to the increment and can be continued indefinitely without endangering future yields.

B. Abnormal Forest: Abnormal forest is one which is not normal, i.e. growing stock, age, class, distribution of stems, increment, etc. are either in excess or more usually in dificit than the normal forest.

Chapter-3

Natural regeneration of forest

Regeneration of Forest

The renewal of a forest by some means (e.g. natural or artificial) is known as regenerations. The regeneration has been defined in a number of ways by several workers.

1) "The renewal of a forest crops by natural or artificial means; also the new crop so obtained".

2) Regeneration as, "The renewal by self-sown seed or by vegetative means." It is of two types viz., Natural regeneration and Artificial regeneration.

Methods of Regeneration:

There are following methods of regeneration of forest:
A) Natural Regeneration,
B) Artificial regeneration and
C) Natural regeneration supplemented by Planting.

However, first two methods are most important in regeneration of forests.

A) Natural Regeneration:

The renewal of a forest crop, by self-sown seed, or by coppice or root-suckers, also the crop so obtained or also it can be defined as Reforestation of a stand by natural seeding.

B) Artificial Regeneration:

It is defined as the renewal of a forest crop by sowing, planting, or other artificial methods; also the crop so obtained or the renewal of a tree crop by direct seeding, or planting.

Site Preparation for Regeneration of Forest

The site preparation is used to create an environment suitable for establishing the desired tree species

1) To get rid-off logging slash or other debris
2) Reducing competition and animal habitat
3) To prepare a mineral soil seedbed
4) To improve drainage of surface and upper soil horizons and reduce the compaction

5) To create a more favorable micro site on harsh sites
6) To take measure to control disease.

Site Preparation Methods:

Following four methods of the site preparation are commonly used all over the world:

i) Mechanical
ii) Prescribed Burning
iii) Chemical and
iv) Combinations of the three.

i) Mechanical Method of Site Preparation for Regeneration: There are several methods employed for carrying out the site preparation mechanically. Following are some of the common mechanical methods:

a) Logging: This is the most common practiced method of site preparation. In this method, logging equipment is used for removing the vegetation and slash.

b) Scalping: This is nothing but the site preparation by hand cleaning.

c) Mechanical Cleaning: In this method self-propelled or the tractor drawn equipment are used.

ii) Prescribed Burning: Fire is a nature's principal method of preparing sites for a new stand.

iii) Chemical Method: The herbicides may be used in new burns and the cuttings, non or poorly stocked parts of plantations, or in existing bushy fields.

Factors Affecting the Choice of Forest Regeneration Method

It is very important to make a choice of method of site preparation. In this case, there are, a number of factors influencing the choice of site preparation method. Following are the seven factors which play a vital role in the choice of method:

1) The nature of existing ground cover,
2) Physical site factors,
3) Site preparation requirement,
4) Available labour and equipment
5) External constraints,
6) Environmental impacts and
7) Cost incurred in the operation.

Natural Regeneration of Forest

Regeneration from seed or vegetative parts may observe in Natural Regeneration. Reforestation of a stand by Natural seedlings

1) Natural Regeneration from Seed: Successful natural regeneration from seed depends upon Seed production, Seed dissemination, Seed germination, Establishment and seedlings.

a) Seed Production: Seeds are cultured ovules, which contain the embryo. An embryo is a miniature plant consisting of seed leaves (cotyledons) attached to rudimentary stem (hypocotyl) with a growing tip (Plumule) and a root tip (radicle) at the other end. Seed production depends upon various factors such a species, age of tree, site, weather conditions, season of maturity, alternate bearing, attack of pests and diseases and birds.

b) Seed Dissemination: For the continued existence of a species, it is necessary that seeds are carried away from the parent plant, because seeds germinating immediately below the parent tree commonly do not get established. Seed dissemination gives young seedlings a better chance of survival for they are saved to a large extend from competition with the parent plant. The means of dispersal adopted by the seeds of different species vary widely. The four important agencies by which seed dispersal is secured are i) Wind, ii) Water, iii) Animals, iv) Explosive mechanism or ejection mechanism in fruit itself.

c) Seed Germination: Germination of seed depends upon several internal and external factors such as Permeability of seed coat, Availability of moisture in seed, Oxygen, Nature of embryo (dormancy), Temperature, Moisture in soil, Oxygen and light. Besides this some factors,

1) Age of Tree,
2) Flowering Phase,
3) Sound or health of seed condition,
4) Coppice origin trees,
5) Size of seed,
6) Plant per cent,
7) Type of dissemination,
8) Soil type / nutrition,
9) Pest and disease,
10) Non insect pests.

d) Seedlings Establishment: Successful establishment of newly germinated seedlings in sufficient number as a member of forest crop is undoubtedly, the weakest link in the whole chain of process (a to c) which make up the regeneration of forest crops.

The Factors Responsible, for Seedlings Establishment are as:

1)Climate: Light / moisture rainfall / temperature / frost
2) Edaphic - Soil / nutrient / aeration / texture / structure.

II) Natural Regeneration by Coppice and Root Suckers: Coppice : Stool shoots generally arise from the adventitious buds formed between the wood and the bark of the stump and are comparatively short lived than those produced by dormant buds. These shoots are called coppice shoots.

Classification of Coppice Regeneration:

1) Seedlings Coppice
2) Stool Coppice and
3) Root collar Shoots
4) Pollard Shoots

Natural Regeneration by Root Suckers: Shoots arises from the roots, may occur naturally or artificially.

Chapter-4

Artificial Regeneration:

Regeneration by Artificial Method

The deforestation is still continuing and takes a heavy toll of forest wealth. This not only affects the forests but the wildlife and the whole ecosystem also. Deforestation is on alarmic rate (1.5 million hectare every year). For carrying out artificial regeneration, there are some preliminary considerations which are urgently needed.

Basic steps of artificial regeneration:

1) Choice of Species:

i) The choice of species is very important in artificial regeneration. Therefore, before choosing the tree species, the purpose of growing the trees has to be specified.
ii) Climate and microclimate: The choice of species depends upon the prevailing climatic and micro-climatic conditions.
iii) Soil requirements: a) Wet soils - Salix species, Populus species, etc. b) Water - logged soils, Eucalyptus robusta, E. saligna etc. c) Sandy loam - Albizia procera, Acacia nilotica, Dalbergia sissoo, etc. iv) Market faci ities :
v) Growth rate: Fast growing tree species - Acacia nilotica (Babul), Leucaena leucophala (Subabool), Melia azedarach (Bakain), P. deltoides (Poplar), Salix species (Willow)
vi) Availability of Exotics: In simple it meaning pertains to, not native to the area of question. The exotic can be described as "an organism in an area which is not native of the area but has its origin in some other region. For example, Eucalyptus species, Leucaena leucocephala, Robinia pseudacacia, Populus deltoids etc.
vii) Base of extablishment.
viii) Management objectives. The artificial regeneration depends upon the objectives of management.
ix) Site conditions: The site is the complex of physical and biological factors of an area that determine what forest of other vegetation may ^arry.
x) Succession: The succession is the gradual replacement of one community by another in the development of vegetation towards a climax.
xi) Cost of growing: This is also very important factor affecting the choice of species.
xii) Availability of seed /propagation material : The seed source should be sound.

2) Choice of Method: The success of artificial regeneration depends, to a great extent upon the choice of method. There are mainly two methods of this regeneration, viz. i) Sowing and, ii) Planting.

i) Sowing: Sowing, in the simplest words, is the process of scattering the seeds in a particular place e.g. nursery bed, field etc.

Advantages of Sowing:

a) It is the cheapest method and costs less,
b) Sowing is direct method and no other complications,
c) It takes less time and thus the work is completed soon,
d) In sowing method, there is no question of disturbances of roots.
e) Sometimes, sowing is done directly in the field (in forests), and hence it does not require any nursery.
f) The sowing being the simple method, is supposed to be less cumbersome.

ii) Planting: Planting is another method of artificial regeneration. However, planting is described as the transferring nursery stock to the planting site as contrasted with transplanting in the nursery.

Advantages of Planting:

a) More Success, b) Less seed needed c) No damage, d) Cheaper weeding

Disadvantages of Planting:

a) Need of nursery
b) Disturbance of roots
c) Time consuming,
d) Need of skilled labour
e) Incurred high costs

3) Site Selection: The selection of site is also a crucial factor in artificial regeneration. There are several factors which affect the site preparation.

Following are the factors which are essential to carry out the preparation:

1) Ground Cover:
2) Physical Factors: a) Topography, b) Exposure, c) Soil type, d) Erosion hazards, e) Size of treatment area and f) Access
3) Preparation requirement: To create a suitable environment for establishment of desirable species.
4) Man Power and Equipment: The site selection and preparation methods require good skill and useful equipment.
5) External Constraints: a) Legal responsibilities, b) Smoke management guidelines, c)

Proximity to sensitive areas and d) The attitude of adjacent farmers / land owners.
6) Spatial Arrangement: This is also called as Spacing.

Artificial Regeneration by Vegetative Method:

Planting material besides seeds for e.g. Bare root seedlings, containerized seedlings, cuttings, layering, rhizomes, suckers, offsets, bulbs, corms are also used for vegetative propagation material.

Propagation by Cuttings: Cuttings are of two types, 1. Stem cutting 2. Root cutting

1. Stem Cutting: Very few species response well for this method. The species, which easy to root are suitable for this method of planting. Particularly species of di-cotyledons group having active cambium layer e.g. Shisam, Nimbara Drumstick, Mulberry Inga dulsis, Dhaman, Pangara, Pimpal, and Banyan Tree etc.

Depending upon the maturity of stem cutting are grouped into:
i) Hard Wood Cutting: Mature woody branches are used.
ii) Soft Wood Cutting: Recently mature branches are used e.g. mulberry-Inga dulsis.
iii) Root-cutting: Roots are used for preparation of cutting e.g. Sandalwood, Pangara.

2. Stumps: In few species, stumps are used for planting e.g. Teak, Shivan, Shisam, Cassia spp. Stums are easy to transport, require less space and can be transported to long distance. These are prepared at the time of planting operation or just before planting operation. Fresh uprooted seedlings are used to transplant easily. 20% stem portion and 80% taproot is kept while preparing the stump. Fine edge knife or implement is to be used so as to avoid the damage, stem portion is cut 5 to 6 cm above the collar region is kept intact and remaining portion or roots are cut to prepare stump. The stumps are then packed in bundles, keeping stem portion on one side and roots on another side, the stumps should be transported immediately. For transportation stumps are covered with moist gunny bag cloth to avoid desiccation. They can be transported within 2-3 days without much loss.

These stumps are planted on start of monsoon after 3-4 rain showers when soil becomes sufficiently moist and soil temperatures are warm. Stumps are planted by preparing small holes in slating portion with the help of crowbar so that new shoot will rise straight. Then the stumps are inserted inside and soil is pressed firmly so as to avid water stagnation in the hole. The cooler region is kept just near to the soil surface.

3. Root Suckers: Root suckers can also be used for planting purpose e.g. Pomegranate, Kokum, Salaim Anjan, Shisam, Nimbara, Pangara, Erythrona etc. The layers, grafted plants, budded plants can be used to prepare planting material. These all are only used in forestry for conservation of superior genotype. It is used for commercial plantation as they are short lived, spreading and not develop long straight (trunk), particularly suitable for timber purpose.

Planting by root cuttings in sandal wood, pangara. Planting by root suckers e.g. Pala, Anjan, Pomegranate, Kokum, Salai, Shisam, Nimbara, Erythrina Supersa.

Chapter-7

Tending Operations in Silviculture:

For establishment of the regeneration and subsequent development of the forest crop up to harvesting, several operations are carried out. These operations are carried out in the forest crop at different stages of growth in order to provide a healthy environment for their development. These operations are called tending operations includes:

i) Weeding
ii) Cleaning
iii) Thinning,
iv) Improvement Felling,
v) Pruning
vi) Climber Cutting

i) Weeding:

Weeds may be controlled by following methods:

a) Mechanical Methods
b) Biological Methods
c) Chemical Methods

ii) Cleaning:

Cleaning is carried out in a crop which has not crossed the sapling stage and is defined as the cutting made in order to face the best individuals from undesirable one of the same age which interfere or are likely to interfere with the growth of the desired individuals. The greatest advantage offered by cleaning is the-proper regulation of the composition of the crop, particularly in mixed crops.

Methods of cleaning may be mechanical, biological and chemical as described under weeding.

iii) Thinning:

Thinning is defined as a felling made in an immature stand for the purpose of improving the growth and form of the trees that remain, without permanently breaking the canopy. Thinning is a tending operation carried out in a crop beyond the sapling stage and up to the beginning of regeneration period. Thinning principles are so formulated that these are applicable only to pure even aged or relatively even, aged crop or even aged groups of the trees in a crop.

Thinning principles have been developed on the basis of natural development of the stand. Thus, thinning, takes place naturally in a density stocked forest under the law of Survival of the fittest.

Method of Tending Operation - Thinning

Following Methods of Thinning can be Adopted:

1) Mechanical Thinning,
2) Ordinary Thinning,
3) Crown Thinning,
4) Free Thinning,
5) Crab's Advance Thinning,
6) Numerical Thinning

1) Mechanical Thinning:

This type of thinning is usually applied in young crops or young plantations before the crown differentiation has taken place. In teak plantations of Kerala, first and second thinning carried out at the age of 4 and 8 years are usually mechanical thinning and consists of the removal of alternate diagonal lines or rows of trees reducing the stocking from 2,500 trees per ha to 1250 trees per ha after the first mechanical thinning and then to 625 trees per hectare after second thinning with spacing 2 in x 2 in to about 2.85 in x 2.85 in and then ultimately to 4 in x 4 in after second thinning.

2) Ordinary Thinning:

This is called as "Low Thinning". In ordinary thinning, the trees are removed from lower crown classes. Ordinary thinning has been devised to follow the nature i.e. those trees, which have been unsuccessful in the struggle of existence, are removed first. Ordinary thinning is the most commonly used thinning practice in forestry. It is most for light demander species. This method of thinning is useful and may be economically applied in species and areas where small size timber has a market.

The method is simple in execution. Removal of lower crown classes suitable for area where there is no danger of soil deterioration. Forests infested with climbers and where there is risk of crown fire. Ordinary thinning has several commands.

Grades of Ordinary Thinning:

i) Light Thinning (A Grade): This is limited to the removal of dead, dying, diseased and suppressed trees.

ii) Moderate Thinning (B Grade): This consists in the further removal of defective eliminated stems and whips.

iii) Heavy Thinning (C Grade): This consists in the further removal of the remaining dominated stems and such of the defective co-dominants as can be removed without making

lasting gaps in the canopy.

iv) Very Heavy Thinning (D Grade): The distinguishing features of this grade is that, it also takes some of the dominate, subject to the some condition of not making any lasting break in the canopy.

v) Extremely Heavy Thinning (E Grade): This is the heaviest thinning that can do in a crop without making permanent gaps in the canopy. More of the dominant stems even of class (a) are removed.

3) Crown Thinning:

The less promising one being removed in the interest of the best individuals; the dominated and suppressed stems are retained unless they are dead, drying or diseased. Aims at removing the inferior trees from among the dominant class.

Advantages of Crown Thinning:

Crown thinning offers several advantages over other methods of thinning:

i) Crown thinning provides better environment for growth and development of retained dominant trees.
ii) The trees of lower crown classes are not removed.
iii) The pressure of trees of lower crown classes results better pruning of side branches.
iv) It helps in protection of the site and reduces the damages due to frost, snow, wind etc.

Disadvantages of Crown Thinning:

The main disadvantages of crown thinning are

i) There is higher root competition for moisture and nutrients.
ii) Abstraction in felling, logging and extraction of tinned material.
iii) Crown thinning is more flexible method than ordinary thinning. It requires greater skill in execution.
iv) Closer look on suppressed and dominated trees would be necessary.

Chapter-11

Agro-forestry

Agro-forestry is an old concept. Trees, crops and animals have traditionally been raised together on small farms throughout the World. This concept first derived in the temperate zone due to the small family farms, as a result trees, crops and animals become separately managed on a large scale in modern agriculture and forestry. In India also we exploited our natural resources and adopted this sectorial policy.

In our country the functional allocation on land is 46.4% for Agriculture and 22.7% area for forestry is not sufficient for meeting the multi ferrous requirement of growing population for food, fodder and fuel and other raw materials. The only answer appears to be to integrate the land used for agriculture and forestry in such a way as to maximize production of foods and services for diverse requirements rural communities.

Modern Agro-forestry establishes a symbiosis among agricultural crops tree species and livestock rising. In other words, these are complementary and beneficial to each other.

In short conventionally there had been separation between Agriculture and Silviculture. From immemorial on a limited scale a combination of food crops and forest crops had been adopted in land management by the farmers throughout the world, however due to steep rise in the demand for fuel wood and food, due to increase of population, present and early and urgent necessity to adopt the scientific approach on a large scale to the dual system of production or co-existence of forestry and farm council of research for FAO set Agroforestry in 1878 and it is a landmark in history in Agro-forestry. Growing of forest crops along with food grains in dual system has been extensively being adopted world over by the farmer.

Agro-forestry is defined as an efficient, integrated and sustainable land use system that combines Agricultural crops, Forest corps and / or Livestock together on the unit of farmland at the same time or in sequential manner. In an Agroforestry there are both ecological and economical interactions between the various components.

Agro-forestry is collective name for land used systems involving trees combined with crops and / or animals on the same unit of land.

It combines production of multiple outputs with protection of resources.
It places emphasis on the use of multiple indigenous trees and shrubs.
It is particularly suitable for low input conditions and fragile environment.
It is structurally and functionally more complex than mono culture (single crop culture) the cycle of Agroforestry system is always more than one year.

Scope of Agro-forestry In India

There is tremendous scope for Agroforestry because India has achieved self-sufficiency in food production. Now its attention is becoming more focused on the ecological problems and shortage

of fuel, fodder and other outputs as well as unemployment. Agroforestry has vast scope in meeting this requirement through multipurpose tree species as:

(I) large area is available in the form of farm boundaries, bunds, waste lands where this system can be adopted
(II) This system permits the growing suitable tree species in the field where most annual crops are growing well
(III) By growing trees and crops on Agricultural or forest land, Resources are utilized efficiently
(IV) System has potential generate employment.
(V)Provides raw material for the cottage industries
(VI) Helps in maintaining ecological balance
(VII) Soil and water conservation, soil improvement.
(VIII) Helps in meeting various needs of growing population.

Benefits from Agro-forestry

Combining trees with food crops on cropped farms yield certain environmental benefits such as,

1. Reduction of pressure on Forrest.
2. More efficient recycling of nutrients by deep rooted trees on the site.
3. Better protection of ecological systems.
4. Reduction of surface run-off, nutrient leaching and soil erosion.
5. Improvement of microclimate, such as lowering of soils surface temperature and reduction of evaporation of soil moisture due to mulching and shading.
6. Increment in soil fertility through addition and decomposition of litter fall.

Economical Benefits:

Agro-forestry brings significant economic benefits to the farmers, the community, the region and the nation such as:
1. Increment in outputs of food, fodder, fuel wood, timber and organic matter.
2. Reduction in incidence of total crop failure.
3. Increase in levels of farm incomes due to improved and sustained productivity.

Social Benefits:

1. Improvement in rural living standards from sustained employment and higher income.
2. Improvement in nutrition and health due to increased quality and diversity of food.
3. Provides stability to rural peoples.
4. Ecological balance.
5. Pollution reduction.

Limitations of Agro-forestry

Agro-forestry does have Certain Negative Aspects:

1. Possible competition of trees with food crops for space, sunlight, moisture and nutrient which may reduce crop yield.
2. Damage to food crops during harvesting of trees.
3. Potential of trees is serving as hosts to insects and birds.
4. Rapid regeneration of profile trees may displace food crops and take over entire fields.

Through skilled management practices any or all these aspects can be controlled. For example, once it is known that trees complete with food crops and may reduce food yields, it is easy to adopt some of the following strategies.

1. Select legume trees that have small or light crowns so that sunlight will reach the food crops.
2. Select trees that are deep-rooted so that they will also absorb moisture and nutrients from the deeper subsoil.
3. Space the trees further apart to reduce their competitive effect on the food crop.

Classification of Agro-forestry System

Different types of Agroforestry systems exist in different parts of the world. These systems are highly diverse and complex in character and functions. To evaluate understand and seek to improve them requires their classification into different categories. Several criteria can be used in classifying them, but the most common include the system's structure, functions, and socio-economic scale of management and ecological spread. According to Nair (1987), Agro-forestry systems can be classified according to following sets of criteria.

1. Structural Basis:

Consider the composition of the components; specially refer including spatial admixture of the woody component, vertical stratification or the component mix and temporal arrangement of different components.

2. Functional Basis:

This is based on the major function or role of the system; mainly of the woody components (This can be productive or protective).

3. Socio-economic Basis:

Consider the level of inputs or management (low input, high input) or intensity/scale or management and commercial goals.

4. Ecological Basis:

Take into account the environmental conditions on the assumption that certain types of systems can be more appropriate for certain ecological conditions.

Classification of Structural Basis Agro-forestry System:

In these systems the type of component and their arrangement are important. On the basis of structure, Agroforestry systems can be grouped into two categories

I. Nature of components
II. Arrangement of components.

I. Nature of Components:

(A) Agri-silvicultural Systems
(B) Silvipastoral Systems
(C) Agro Slivipastoral Systems
(D) Other Systems

II. Arrangement of Components:

(A) Spatial Arrangement
(B) Temporal Arrangement

Silvipastoral Systems (Tree+ pasture/animal)

The production of woody plants combined with pasture is referred to as Silvipastoral system. The trees and shrubs used primarily to produce fodder for live stock. This system is needed in dry area to meet the fodder demand throughout the year. In this system forest tree species for fodder purpose like Anjan, Subabhul, babhul, Hadag, Shevari, Tamrind, Bakan, Neem, Vilayti Chinch etc. are taken at 10-12 m distance in rows in between the lines the grasses like Burseem, Luscrn, Hameto, Stylo etc. are taken as intercrops. This system is suitable for providing the fodder for milch cattle and thus for development of dairy industry.

There are Three Types of this System:

a) Protein Bank:

Protein rich multipurpose trees are raised on and around farm lands like Subabhul Anjan Delbergia sissoo, Zizyphus species, Acacia species, Prosopis juliflora, Bomabx mulbericum, Sesbenia spp. etc. are planted.

b) Live Fences:

Fodder trees are raised in the form of hedges or fences e.g. Sisbania gandiflora (Hadga), Sisbania egyptica, Prosopis juliflora, 1 ricidia maculata, Carissa carandas, Bambusa species and Erythrina Indica.

c) Trees and Shrub on Pasture:

Fodder, trees and shrub are raised scattered the pasture land e.g. Emblica, Tanirindus, Ficus, Bakan, Anjan, Khejadi.

Agri-Silvipastoral System

(Tree Crops + Grain crops + animals) This is the system in which the forest tree crops for fodder like Anjan, Subabhul, Babhul, Tamrind, Hadga and Khejedi etc. are taken with intercrops of grasses like Stylo, Burssem, Haemeto are taken for fodder purpose as well as the food grain crop like Wheat, Rice, Jowar etc. are taken in between the strips of forest tree species. The forest tree species are planted at 10 to 12 m distance and in the lines the grasses and food grains are cultivated as intercrops.

Following are the Types of Agri-Silvipastoral System:

i) Home Garden:

This is one of the oldest agroforestry practices found extensively in high rain fall areas in tropical South East Asia (Kerala and Tamilnadu). Many species of trees, shrubs, Vegetables and other various plants are grown near about the home which supports the variety of animals. Fodder and legumes are widely grown to meet the daily fodder requirement of cattle. The waste material and wastes from home are used for fodder and barn waste is used as manure for crops. Every home stead has around 0.2 - 0.5 ha of land for personal production. These home gardens represents land use system involving deliberate use of multipurpose trees and shrub along with annual crops and animals within the compound of individual houses. This system is highly productive and extremely sustainable and practicable. In Kokari and Kerala following crops are taken in the home gardens. Mangifera indica, Cocus pucifera, Anacardiumofficinale (Cashewnut), Garcainia indica (Kokum), Arecanut, Tea, Coffee plus medicinal plants like Black pepper, Cardiamum, Allspice cumen etc.

ii) Woody Hedge Rows:

In this system, various woody plants and shrub are grown in the form of hedges especially fast growing and coppicing. Fodder trees/shrubs are planted for the purpose of fodder for cattle, green manure and soil conservation. Prosopis juliflora, Anjan, Carisa carandes, Hadga, Bakan etc. are planted for hedges.

Other Agroforestry System

In which following systems are included,

a) Horti-pastoral System:

Cultivation of Horticultural crops plus pastures.

b) Agri-Horti-Pastoral System:

In this system, in the marginal lands the fruit crops like Mango, Ber, Anona, Jamun, Tamrind, Wood apple etc. are taken along with forest trees and the food grains like, Peas, Gram, Wheat, Rice, Vegetables are taken.

c) Apiculture with Trees:

In this system, the flowering trees like Kanchan Jacaranda Spathodia, Erythrina, Krate sawar, Palas are planted for producing the honey in addition to Jamun, Mahuha, Ecualyptus like trees are also planted for honey collection.

d) Aqua Forestry:

Plants grown on the boundary around fish ponds like Casuriana, Coconut, Arecanut, Kokum, Babhul, Bamboo, etc.

e) Multipurpose Wood Lots:

The specific multipurpose trees are grown mixed or separately on the farm like Australin babhul, Euclayputs, Subabhul, Bakan, Bamboo etc.

Multipurpose Trees, Forest tree Combination with Plantation Crops and Agroforestry Fuel Wood Production

Multipurpose Trees / Shrubs on Farm:

In this system multipurpose tree species like *Azadirachta indica*, *Cocos nutifera*, Bamboo, Acacia species. Mango are scattered haphazardly or according to certain pattern on bunds terraces or bounders. The primary role of this system is to meet various needs of grower for food, fodder, timber, soil conservation or protection of farm.

Forest tree Combination with Plantation Crops:

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

a) Integrated multi story cropping of plantation crops.
b) Shade trees for plantation crops coffee and silver oak and Erythriva spp. Betel vine +sesbania spp. +Erythrina spp.
c) Intercropping with Agril. crops: Ginger/cardamum/ pepper/ are grown with trees.
d) Mixture of plantation crops in alternate arrangement.

Agroforestry Fuel Wood Production:

In this system, various multipurpose fuel wood / fire wood species are interplanted, on or around agricultural lands. The primary productive role as fencing, boundary demarcation tree spp. commonly used Acacia nilotica, Cassia siamea, Casuarina eqnisefifolia, Prosopes juliferous, Eucalyptus spp.

Multispecies Tree Gardens and Alley Cropping (Hedge Row Intercropping)

Multispecies Tree Gardens:

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

Major woody species involved, coconut, Arecanut, Artocarpus spp. Phoenix dectillifera, Acacia, catechu.

Alley Cropping (Hedge Row Intercropping):

This system involves managing rows of closely planted woody plants with the annual crop planted in alley in between hedges. The woody plants are cut regularly and leaves and twigs are used as mulch on the cropped alley in order to reduce evaporation from the soil surface suppress weeds and add nutrients to the soil, N fixing plants are the main component of the hedgerows. The primarily purpose of alley cropping is to maintain or increase crop yield by improvement of the soil and microclimate and weed control. Farmers may also obtain the products from the hedgerows, including fuel, poles, food etc. and fodder. Alley cropping usually works best in places where people feel a need to intensity crop production but face soil fertility problems.

Design:

Without doubt, trees compete with farm crops for soil nutrients, soil moisture and light. However, the right kind of trees at the right spacing, with proper management may actual by produce a net increase in yield.

The position and spacing of hedgerow and crop plants in an alley depend on plant spp. Climate, slope, soil conditions and convenience. In general, hedgerow should be placed in E-W direction at the distance of 4to 8m. The closer spacing is generally used in humid areas and the wider spacing in semi-arid regions.

On sloping land hedgerows should always be placed on the contour. Usually leguminous trees/shrubs are included to improve soil fertility. Tree/shrub spp. for alley should have following characteristics.

i) It should have a sparse and small crow to permit sunlight to pass through.
ii) It should be capable to respond rapidly.
iii) It should form deep root system.
iv) It's leaf litter should decomposes at faster rate.
v) It should be capable to fix atmospheric nitrogen.
vi) It should be useful as wood, food, and fodder etc.
vii) It should be hardy enough to tolarate saline/acidic/ drought/waterlogged conditions.
viii) Glyricidia sepium, Sesbania spp., Leucaena leucocephala, Casea spp. Gmnelia arboria are commonly used in alley cropping.

Improved Fallow Species in Shifting Cultivation

Fallow are cropland left without crops for a period ranging from one season to several years. The objective of improved fallow species in shifting cultivation is to recover depleted soil nutrients. Ones the soil has recovered crops are reintroduced for one more seasons.

Shifting cultivation as the term implies, is a pattern of land use and a system of production of crops under which plots of land are cleared, cultivated for a short period for raising crops, after which the land is allowed to rest longer than the period of cultivation. It is a system of production almost without capital inputs.

This system is practiced extensively the north-eastern hill region comprising the states of Assam, Meghlaya, Maniput, Nagaland and Tripura (Arunachal Pradesh and Mizoram). To some extent in Andra radesh, Bihar, Madya pradesh, Orissa and Kernataka. It is called as JHUM in the north eastern hill region and PODU, in A.P. and Orissa and considered most destructive for forest areas.

The main features of the improved fallow system of Agroforestry is that trees and shrubs.

Are not grown with crops on the same land, the best species for the fallow system should be include good N fixation in the soil.

The main function of the fallow is to maintain or restore soil fertility and reduce erosion some plants can be introduced primarily for their economic value.

Establishment:

Improved fallow can be established in a variety of ways and at various stages of the fallow methods. Direct seeding of clean filled harvest plots and Selective cutting of bush followed by enrichment planting with tall plants. Introducing tall seedlings and cutting into poor quality fallows.

Shelter Belt and Wind Break

Shelter Belt:

These are belts / blocks consisting of several rows of trees established at right the purposes are:

(a) To deflect air currents
(b) To reduce the velocity of winds.
(c) To provide general protection to the leeward areas against the effects of wind erosion.
(d) To protect the leeward areas from desiccating effects of hot wind.
(e) To provide fuel, fodder timber etc.

Characteristics of Shelter Belts:

a) Shape and Composition: Shelterbelts have a spiracle, triangular shape by raising tall trees in the centre.
b) Density and Width: Shelterbelts up to 50m width are considered ideal under Indian conditions. A certain degree of penetration by wind is planned.
c. Orientation: Orientation depends on the direction and velocity of the winds.
4. Length: The minimum length of a shelterbelt should be about 25 times its height.

Dodonaia viscosa, Cassia sp., Clerodendron, Acacia arabica, Dalbergia, Eucalyptus, Parkinsonia, Prosopis etc.

Wind - Break:

Wind-breaks are strips of trees and or shrubs planted to protect fields, homes cannels or other areas from wind and blowing soil or sand.

Purpose of Raising Wind Breaks:

1) To protect field crops / livestock from cold / hot wind.
2) To prevent soil erosion.
3) To reduce evaporation from farmlands.
4) To improve the microclimate.

5) For fencing and boundary demarcation.
6) For productive role-fuel, fodder, etc.

Main Features of Wind Break:

a) Permeability:

The primary purpose of raising windbreaks is to filter and break up the force of the wind. Permeable windbreaks, which allow some wind to pass through, are the most suitable. The desired permeability can be obtained by carefully selecting trees and shrub species. Species such as Eucalypru and Casuarina will form dense mind break but most native species are more permeable.

b) Orientation:

For best results, wind-breaks should be-raised at right angles to the direction of wind. N - S direction is good compromise. They should give better shading of adjacent crops and pastures.

Taungya System

Taungya is Burmas ward meaning hill cultivation, it was introduced into-India by Dr. Brandis in 1890 and the first Taungya plantation was raised in 1896 in north Bengal. It is practiced in Kerala, West Bangal, U.P., and to lesser extent in Tamil Nadu, A. P. Orissa and the north eastern hill regions. In southern India the system is called KUMARI, it is practiced in a areas with an assured annual rainfall of over 1200-1500mm.

This is a modified term of shifting cultivation in which labour is permitted to raise crop in an area but only side by side with the forest species planted by them. The practices consist of land preparation, tree planting, growing agricultural crop for 1 to 3 years until shade becomes the dense and then moving on to repeat the cycle in a different area.

Traditional Taungya consist of land preparation for tree plantation, growing agricultural crops for 1 to 3 years after the tree plantation and moving on to another area to repeat the cycle. There are three types of Taungya .

a) Departmental Taungya:

Under this, agricultural crops and plantation are raised by the forest department. By employing daily paid labours the main aim of raising agril. crops along with the plantation is to keep along with the land free of unwanted vegetation.

b) Leased Taungya:

The forest land is given on lease to the person who affects the highest money for raising Agril. crop for a specialized number of years and ensure care of tree plantation.

c) Village Taungya:

This is the most successful of all the three Taungya systems. Under this the people who have settled down in a village inside the forest for this purpose raise crops. Usually each family has about 0.8 to1.7 ha of land has raise trees and cultivate crops for 3 to 5 years.

Advantages of Taungya System:

i) Artificially regeneration of the forest is done at cheaper rate
ii) Problem of unemployment is solved to some extent
iii) Better utilization of land
iv) Remunerative to forest department

Disadvantages of Taungya System:

i) Creates certain legal problems
ii) Exploitation of hum in labour
iii) Danger of epidemic
iv) Provision
v) Loss and soil fertility

Classification of Agroforestry Based on Arrangement of Components

The arrangement of components gives first priority to the plants. Even in Agroforestry systems involving animals, their management according to a definite plan.

1) Spatial Arrangement:

Spatial arrangements of plants in an Agroforestry mixture may result in dense mixed stands (as in home gardens) or in space mixed stands (as in most systems of trees in pastures). The species (or species mixtures) may be laid out in zones or strips of varying widths. A common example of the zonal pattern is hedgerow intercropping (alley cropping).

2) Temporal Arrangement:

Temporal arrangements of plants in Agroforestry may also take various forms. An extreme example is the conventional shifting cultivation cycles involving 2-4 years of cropping and more than 15 years of fallow cycle, when a selected woody species or mixtures of species may be planted. Similarly, some silvopastoral systems may involve grass leys in rotation, with some

species of grass remaining on the land for several years. These temporal arrangements of components in Agroforestry are termed coincident, concomitant, overlapping (relay cropping), separate and interpolated.

Classification of Agro-forestry System on Functional Basis

This classification based on the major function or role of the system. Mainly on the woody component, this can be as productive or protective.

a) Productive Functions:

i) Supply of Food:

The tree species in agroforestry mainly fruits and nuts can supply food to the increasing population. The fruit trees like Mango, Ber, Jackfruit, Jamun, Tamrind, Wood apple, Bael, Caronda can supply the food.

ii) Supply of Fodder:

For 41 cores cattle to feed sufficient quantity of fodder is required which is supplemented by trees like Subabhul, Vilayti chinch, Hadga, Shevari, Neem etc.

iii) Supply of Fuel Wood:

The species like Subabhul, Khair, Sissoo, Casurina etc. can supply the fuel wood required for cooking. Thus diverting the cow dung to agriculture.

iv) Supply of Timber:

The agro-forestry can produce the timber wood in addition to the food grains by planting the trees like Teak wood, Eucalyptus, Silver oak, Sal, Arjun, Mohagoni. The timber wood is required for doors, windows, railway sleeper, furniture, poles and post for construction of bridges and for centring.

v) Other Products:

A number of minor forest products like flower medicinal plants, fibre, floss.gum, lac, tannin, resin etc. are obtained and thus, flourish the small cottage industry there by increasing employment.

b) Protective Function:

Protecting and mentioning production systems

1) Wind break
2) Shelter belt

3) Soil conservation
4) Moisture Conservation
5) Soil improvement
6) Shade (from crop animal and man)

Classification of Agro-forestry System on Socio-economic Basis

Based on such socioeconomic criteria as scale of production and level of technology input and management, agroforestry systems have been grouped into three categories

a) Commercial, b) Intermediate and c) Subsistence Systems

Commercial Agro-Forestry Systems:

The term commercial is used whenever the sale of the production of the output (usually a single commodity) is the major aim of the system the scale of operations is often moderate to large and land ownership may be government, corporate or private. Commercial production of shade-tolerating plantation crops such as coffee, tea and cocoa under over storey shade trees; rotational timber/food crops systems in which a short phase of food-crop production is used as a silvicultural method to ensure establishment of the timber species (various forms of taungya); commercial grazing and ranching under large-scale timber and pulp plantations etc.

Intermediate Agro-Forestry Systems:

Intermediate Agro-Forestry systems are those between commercial and subsistence scales of production and management, production of perennial cash crops and subsistence crops undertaken on medium to small size farms wherein the cash crops cater for the cash needs and the food crops meet the family's food needs.

Subsistence Agro-Forestry System:

Subsistence Agro-Forestry systems are those wherein the use of land is directed towards satisfying basic needs and is managed mostly by the owner/occupant and his family. Cash crops, including sale of surplus production of commodities, and all forms of traditional shifting cultivation are the most widespread examples

Ecological Classification of Agro-forestry Systems:

Based in the major agro ecological zones, agroforestry systems are grouped into the following categories:

1) Humid/sub humid lowlands,
2) Semi-arid/arid lands,
3) Highlands

Agroforestry Systems in Humid/Sub Humid Lowlands:

This is characterized by hot humid climate for all or most of the year and an evergreen or semi - evergreen vegetation. The lowland humid and sub humid tropics (commonly referred to as the humid tropics) are by far the most important ecological region in terms of the total human population it supports, extent of area and diversity of agro forestry and other land-use systems. Because of climatic conditions that favour rapid growth of a large number of plant species, various types of agroforestry plant associations can be found in areas with a high human population, e.g. various forms of home gardens, plantation crops with combination and multilayer tree gardens. In areas of low population density, trees on rangelands and pastures, other silvopastoral systems, improved fallow in shifting cultivation and multipurpose tree wood lots etc. are the major agro forestry systems.

Semi-Arid and Arid Lands:

This region is characterised by rainfalls confined to 9-12 hours per day in July-Sept 2 to 4.5 wet months, vapour pressure deficit ranging from 9 mb in Jan to 30 mb in April-May, solar radiation incidence (400-500 cal/cm2/day), high wind velocity (20 km/hour), high potential evapotranspiration (6 mm/day) and high mean Aridity index (70-74.8%).

Agroforestry Systems in Tropical Highlands:

This area is characterised by uneven topography, varying levels of rainfall, degraded and shallow lands at high altitude to deep rich soils in valleys and great climatic variations. The Himalayan region is an excellent example of this type of area. Land use problems in the highlands are similar to those in humid or dry lowlands, depending on climate, with the addition that sloping lands and step terrier make soil erosion a major concern.

Choice of Species for Agro and Farm Forestry

Following considerations mainly motivate the selection of species in social forestry.

(1) Rapid growth
(2) No competition with field crop.
(3) Fixation of Nitrogen
(4) Easy decomposition of litter or leaves
(5) Fast growth and easy establishment
(6) Ability to regenerate
(7) High yield of wood and fodder
(8) Multiple use of wood like Subabul
(9) Plant with deep tap root system

(10) Plant yielding small timber
(11) Easy in establishment and ability to coppice
(12) Capacity to grow under wide range of environment, soil types, rainfall etc.
(13) For recreation and shade plants with quick growing and give shade and pleasing colour like Spathodia, Gulmohar, Cassia, Jakaranda are selected.

Botanical Name, Common Name and Uses of important Forest Plants

Sr. No	Botanical Name	Common Name	Use or Utilities
1	*Acacia catechu*	Khair	Fodder, fuel, poles, soil conservation and katha
2	*Acacia nilotica*	Babhul	Fodder, soil conservation; agricultural implements, bark as medicine, tannin products and fule
3	*ALadirachta indica*	Neem	Planks, tooth brush and medicine (Bark, leaves gum)
4	*Bombax ceiba, BombaxMalbaricam*	Simal (Kate sawar)	Match Stiks, packing cases, play wood, soil conservation, roots used as medicines
5	*Delbergia sissoo*	Sissoo	Fodder, Timber, fuel, soil conservation
6	*Delbergia latifolia*	Rose Wood	Fodder, Timber, fuel
7	*Melia aadirachta*	Bakan/ Limbara	Avenue tree, fodder, timber
8	*Tectona grandis*	sag / Teak Wood	Structures and industrial timber, furniture, fuel, tannin, ornamental and medicinal use, KING OF TIMBEER
9	*Terrninalia tomentosa*	Asan / Ain	Industrial timber, tannin, gum, medicinal, tassar
10	*Terminalia arjuna*	Arjun	Industrial timber, small poles, fodder, timber, ornamental, tassar
11	*Acacia auriculiformis*	Australin Babhul	Denuded places, tannin, fuel
12	*Acacia chundra*	Lal khair	Timber, pole, fuel, tannin and soil conservation
13	*Aegle marmelos*	Bel	Tooth brush, fruits, medicine (Bark, gum)
14	*Albizia chinesis*	Kala sires	Timber, pole, fuel, tannin

			and soil conservation
15	*Albizia procera*	Safed Siris	Timber, medicine, fuel
16	*Arto carpusus*	Jack Fruit	Fruit and timber
17	*Anthoeephalus chinensis*	Kadamb	Fodder, fiiel, pulp wood, ornamental
18	*Emblica officinalis*	Amla	Fruit, fuel, ornamental, medicinal
19	*Madhuka latifolia*	Mahua	Liquor oil seed, timber, edible flower
20	*mangifera Indica*	Mango	Fruit, timber, medicine.
21	*Tamarindus indica*	Imli	Fruit, fuel, medicinal, timber, leaves, flowers, fodder, poles
22	*Ziziphus jujuba*	Ber	Fruit, fodder, poles, lac
23	*Syzygium cumini*	Jamun	Fruit, fodder, poles, timber, fuel,medicinal (flowers fruits)
24	*Moringa oleifera*	Drumstick	Fruit, fodder, hand paper
25	*Sesbania grandiflora*	Hadga	Flowers, fence poles, tannin fodder, fuel, pulp
26	*Saraca indica*	Ashok	Ornamental, medicinal
27	*Santalum album*	Sandal	Industrial timber, oil, ornamental, medicinal
28	*Mores albs*	Mulberry	Fodder, fruit, sport goods, silk industries
29	*Pongamia pinnata*	Karanji	Leaves used for green manuring branches used as tooth brush seeds for oil, used for soil conservation.
30	*Bauhinia variegata*	Kanchan	Fodder, food, timber, leaves and flowers are used as vegetables, medicine
31	*Bathinia racemosa*	Jhangora	Medicinal plant, ornamental
32	*Barchinia chinensis*	Kanchan	Medicinal and fuel, ornamental
33	*Michelia chamapaca*	Chaffa	Pole, industrial timber, fuel, ornamental, soil conservation, medicinal flowers are more valuable for perfume
34	*Populus deltoids*	Poplar	Pulp wood, fodder, packing cases,soil conservation, fuel match box and splints

35	*Pitheocolobtum dulcis*	Vilayati Chinch	Fuel, hedge, soil conservation
36	*Prosopis chinensis*	Kabuli kikar	Fodder, fuel. soil conservation
37	*Casuarina equisetifolia*	Khadsarni or suru	Fuel, timber, good for plantation in coastal area, charco
38	*Cupressus cashmiriana*	Cypress	Industrial timber, poles, soil conservation sandy area
39	*Eucalyptus camatndulensis*	Eucalyptus	Gum, oil,tannin, soil conservation, industrial timber, paper, pulp
40	*Eucalyptus globules*	Blue Gum	Pulp wood, fuel, timber
41	*Eucalyptus teriticornis*	Mysore Gum	Fuel and pulp wood
42	*Ficus religiosa*	Pipal	Avenue trees, fuel, fodder
43	*Ficus bengalensis*	Wad	Avenue trees, fodder, fuel, fruits, soil conservation, timber for packing cases
44	*Ficus glornerata*	Gular / Umbar	Avenue trees, fodder, fuel
45	*Delonix regia*	Gulmobar	Ornamental,

Sr. No	**Botanical Name**	**Common Name**	**Use or Utilities**
46	*Laucaena leucocephala*	Subabul	Timber, fodder, poles, fuel, soil conservation
47	*Salix spp.*	Willow	Timber, basket making
48	*Sapindus mukorosis*	Ritha or Soapnut Tree	Fuel, soap nut for washing cloth
49	*Swietania mahgoni*	Mahogoni	Poles, gum, tannin, industrial timber, ornamental and soil conservation.
50	*Dendrocalmus strictus*	Solid bamboo	Fodder, poles, industrial use, paper, soil conservation
51	*Bambusa arundinicae*	Hallow bamboo	Fodder, paper, poles, industrial use, soil conservation
52	*Acacia conciana*	Shikekai	Medicinal, fuel, timber, soap
53	*Prosopis guliflora*	Vilayati Babhul	Medicinal, fuel, timber, fencing

54	*Prosopis cinerarie*	Khejadi	Fodder, fuel, timber, fencing
55	*Terminalia chibula*	Hirda	Timber, dye, fuel, medicinal
56	*Terminalia paniculata*	Kingal	Timber, fuel
57	*Terminalia belirica*	Behda	Medicinal, timber, fuel
58	*Potyalthia longifolia*	Drooping Ashok	Ornamental, road avenue
59	*Semicarpus anacardiuin*	Biba	Medicinal, fuel
60	*Cassia renigera*	Pink cassia	Ornamental
61	*Cassia. fistula*	Bahaya / Amaltas	Ornamental, medicinal
62	*Diospyros melanoxylon*	Tendu	Beedi leaves
63	*Plantanus orientalis*	Chinar	Timber, fuel
64	*Diosypros tomentosa*	Temburni	Ornamental, medicinal, fruits
65	*Kigelia pinata*	Monkey Plant	Ornamental
66	*Shorea robusta*	Sal	Timber, fuel
67	*Ailanthus excelsa*	Maharukh	Fodder, match industries
68	*Quercus spp.*	Indian oak	Fodder, fuel, sericulture
69	*Lagerstroemia parviflora*	Sidha benteak	Fodder, fuel, gum, tannin, pole, timber, ornamental
70	*Hardwickia binata*	Anjan	Fodder, fuel, agricultural implements
71	*Erythrina indica*	Pangara	Fuel and soil conservation
72	*Grewia spp.*	Dhaman	Fibre
73	*Pinus roxburghii*	Chir-pine	Rasin, gum, tannin, oil, pole, soil conservation
74	*Jacaranda mimosaefolia*	Neel-mohar	Ornamental and soil conservation
75	*Grevillea rohusta*	Silver oak	Ornamental, avenue tree
76	*Pithecolobium saman*	Rain tree	Ornamental, shade tree, fuel
77	*Spathodia campanulata*	Fountain Tree	Ornamental. shade tree, fuel
78	*Millingtoniahortansis*	Indian cork tree	Ornamental, cork industry
79	*Mimusops elengi*	Bakul	Shade tree, scented flower, rootstock for sapota, avenue
80	*Feronia elephanta*	Wood apple	Fruits, medicine, timber
81	*Anonas uatimosa*	Sitaphal	Fruits, fuel
82	*Cedrus deodara*	Debdar	Timber, fiuniture, flanks
83	*Glyricidia maculata*	Giripushpa	Fodder, leaf manures
84	*Butea monosperma*	Palas	Ornamental, Cottage industry, lack industry

85	*Thespetia papulnea*	Ran Bhendi	Timber, fuel, rural ornamental
86	*Garcinia indica*	Kokam	Fruit, oil industry, squish, oil seed, medicine
87	*Tarminalia catappa*	Wild Almond	Ornamental, oil seed
88	*Manilkaria hexandra*	Khirani	Fruits, fuel, root stock for sapota
89	*Adina cordiolia*	Haldu	Timber, fuel
90	*Gmnelia arborea*	Shivan	Timber, fuel
91	*Lagesrromea lanciolata*	Nana	Timber
92	*Callistemon lanceolate*	Bottle Brush	Ornamental road avenue, parks
93	*Agave american*	Agave /' Ghaipath	Live fencing, rope making
94	*Peltophorum ferroginum*	Pelto phoorum	Ornamental road avenue tree, parks
95	*Anona reticulata*	Ramphal	Fruits, soil reclamanation
96	*Buchanamia latifolia*	Charoli	Fruits, soil conservation
97	*Anacardium occidentale*	Cashewnut	Cashewnut Fruits, soil conservation

Forest Tree Species Used for Different Purpose

i) Industrial Needs: Pulp wood, saw-timber, panel products such as, plywood and other boards, match wood, sport goods etc. constitute the industrial needs. Some of the species for meeting some of the industrial needs are given below:

1. Construction: Acacia catechu, Cedrus deodara, Dalbergia sissoo, Dipterocarpus macrocarpus, Eucalyptus spp., Hopea parvifolia, Mesua ferrea, Pterocarpus santalinus, Shorea robusta, Tectona grandis.

2. Tool handles: Acacia catechu, A. nilotica, Dalbergia latifolia, Diospyros melanoxylon, Mesua furrea, Pterocarpus inarsuipium, Shorea robusta, Terminalia alata.

3. Packin Cases: Abies densa, A. pindrow, Acrorcarpus spp., Ailanthus excelsa, Bombax ceiba, Boswellia serrata, Fiscus spp., Mangifera indica, Kydia calycina, Melia azedarach, Pinus spp.

4. Plywood: Acrocarpus fraxinifolius, Adinacord flora, Dalbergia latifolia, D. sissoo, Dipterocarpus macrocarpus, Gmelina arborea, Mangifera indica, Michelia champaca, Schima wallichii, Shorea assamica, Tectona grandis, T myriocarpa.

5. Doors and Windows: Tectona grandis, Cedrus deodara, Adina cordifolia, Dalbergia latifolia, D. sissoo, Dipterocapus spp., Gmelina arborea, Pterocarpus dalberhioides.

6. Matches: Aillanthus excelsa, Alstonia scholaris, Anthocephalus chinensis, Bombax ceiba, Populus deltoides, Elaecarpus spp.

7. Lorrboyodies: Aerocarpus fraxinifolius, Albizia libbeck, Artocarpus chaplasha, Dalbergia sissoo, D. latifolia, Dipterocarpus mecrocarpus, Pterocarpus dalbergioides, P. marsupium, Shores robusta, Tectona grandis, Terminalia alata, T myriocarpa.

8. Furniture: Tectona grandis, Dalbergia latifolia, D. sissoo, Pterocarpus santalinus, Adina cordifolia, Gmelina arborea, Dipterocarpus macrocarpus, Pterocarpus marsuipium, Cedrus deodara, Juglans regia.

9. Pulp Wood: Pinus spp., Abies pindrow, Picea smithiana, Bamboos, Eucalyptus spp. and other fast grown hardwoods.

10. Sport Goods: The species for various items of sport goods.

ii) Social Needs:

Firewood, fodder, small .timber and poles constitute the social needs. Almost all tree species yield firewood. The important species used for supply of firewood include Acacia nilotica, Leucacaena, Prosopis juliflora, Lagerstroemia spp., Anogeissus latifolia, etc. Fodder yielding species include Leucanea leucocephala, Acacia nilotica, Ficus spp., Azadirachta, Ziziphus spp., Grewia optiva, Celtis australis, Prosopis cineraria, Ailanthus excelsa etc.

iii) Environmental Protection:

Checking water and wind erosion, stabilize soil surface, windbreaks and shelter-belts road, rail and canal side afforestation, rehabilitation of wastelands and industrial sites constitute environmental protection e.g. Acacia catechu, Acacia nilotica, Morus alba, Pupulus delfoids, Swietania Mahagoni.

iv) Land Use Needs:

Tree planting is an integral part of land use for amenity shade, shelter, food, wood, soil productivity, etc. e.g. Artocarpus heterophyllus, Embilca officinalis, Ficus glomerata, Bambusa arundicicae, Hardwickia