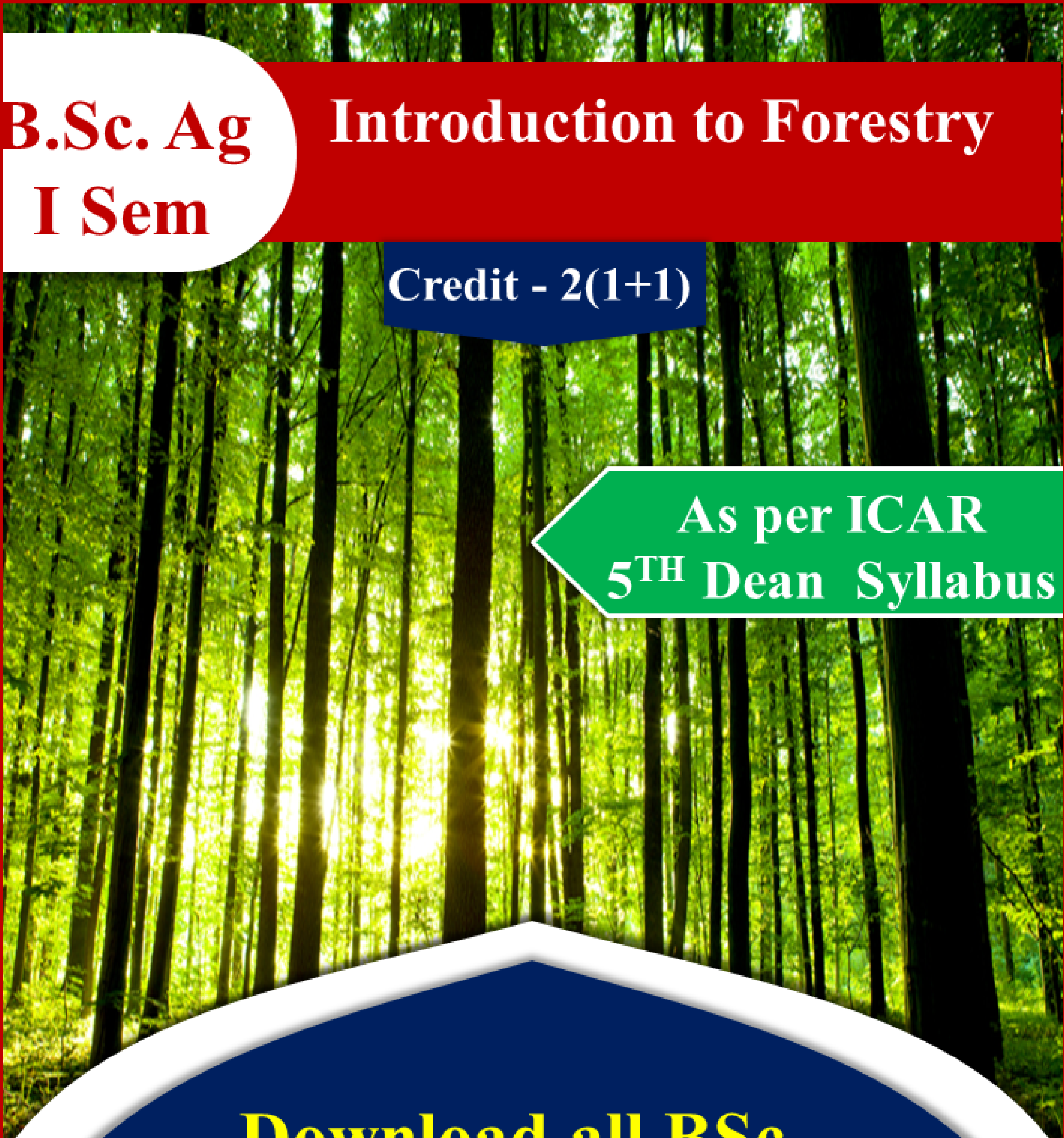


B.Sc. Ag I Sem

Introduction to Forestry

Credit - 2(1+1)

As per ICAR 5TH Dean Syllabus

Lecture	Topic
1	Definitions of basic terms related to forestry, Definition of Silviculture, objectives of silviculture,
2	forest classification- 16 Major types of forest with species composition
3	Salient features of Indian Forest Policies
4	Natural regeneration - natural regeneration from seed and vegetative parts, coppicing, pollarding, root suckers with examples
5	Artificial regeneration – objectives, choice between natural and artificial regeneration, essential preliminary considerations for AR
6	Crown classification of trees
7	Tending operations – weeding, cleaning, thinning – mechanical, ordinary, crown and advance thinning
8	Forest mensuration – objectives, diameter measurement, instruments used in diameter measurement
9	Non instrumental methods of height measurement - shadow and single pole method; Instrumental methods of height measurement - geometric and trigonometric principles, instruments used in height measurement
10	Tree stem form, form factor, form quotient
11	measurement of volume of felled and standing trees, age determination of trees.
12 & 13	Agroforestry – definitions, importance, Classification of Agroforestry systems, criteria of selection of trees in agroforestry
14 & 15	different agroforestry systems prevalent in the country, shifting cultivation, taungya, alley cropping, wind breaks and shelter belts, home gardens with regional examples
16 & 17	Cultivation practices of two important fast growing tree species of the region.

1.
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.
9. **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 (2) Seedling raised from obtained from seeds of superior trees.
10. **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.
11. **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.)

12. **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.

13. **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. **14. Felling:** Felling comprise of removal of trees either singly or in small groups scattered all over the forest.

15. **Afforestation:** Establishing a forest by artificial means on an area on which not forest vegetation has existed for a long time in the past.
16. **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.
17. **Age crop:** The age of a regular crop corresponding to its crop diameters.
18. **Age classification:** The division of a crop according to difference in age **OR** the allotment of woods to age classes.
19. **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.
20. **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.
21. **Bole:** The main stem of a tree.
22. **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” (1.30m)
23. **Coupe:** A felling area, usually one of an annual series unless otherwise stated. Preferable numbered with Roman numbers as, I, II, III etc.
24. **Crown:** The upper branchy part of the tree above the bole.
25. **Dendrology:** The identification and systematic classification of trees.
26. **Reserved forests:** an area so constituted under the Indian Forest Act or other Forests law.
27. **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.
28. **Unclassed forest:** Forest land owned by Government but not constituted in to a reserved, village or protected forest.
29. **Log:** The stem of a tree or a length of stem or branch after felling and trimming.
30. **Logging:** Operation comprising felling of trees, limbing, bucking and transportation of the resulting product out of the forest timber harvesting (Bucking-Act of being)

31. **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.
32. **Raft:** An assemblage of logs, timbers or bamboos tied together or enclosed within a boom for transport by floating.
33. **Scrub:** Inferior growth consisting chiefly of small or stunted trees and shrubs.
34. **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.
35. **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:

- **By Toumey and Korstain:**

Silviculture is that branch of forestry which deals with the establishment, development, care and reproduction of stands of timber.

- **By Champion and Seth:**

The terms silviculture, in English refers only to certain aspects of the theory and practices of raising of forests crops.

- **By Iffprt (IFR Dehradun)**

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.

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.

Functions & Types of Forest in India

Function of forests:

Sr.No.	Particulars	Functions
1	Productive	They provide timer, fuel, charcoal, beedi , leaves, was and resins, fruits, tanning, materials, manure leaves, grass, bamboo, gums, lac etc.
2.	Protective	Forests protect water sheds, catchments of rivers and streams against erosion.
3.	Aesthatic	Forests add good appearance, landscaping and a thrilling atmosphere to the locality.
4	Recreational	Forest provides picnic resorts and opportunities for sport like hiking, trekking, wild life watching, bird watching.
5	Scientific	Study of ecological process can be made
6	Ameliorative	Forests improve climate and reduce pollution
7	Hygienic	Forests improve the environment and help in reduction of noise, purify the air and give out oxygen to the atmosphere.
8	Industrial developments	Forest meet the need for raw material for industrial development such as Paper pups, rayon grade pulp, saw milk ply wood, hard board etc.

2.
Classification- 16 Major types of forest with species composition

Classification of Natural Vegetation of India is primarily based on spatial and annual variations in rainfall. Temperature, soil and topography are also considered.

India‟s vegetation can be divided into 5 main types and 16 sub-types as given below.

Classification of forest

A. Moist Tropical Forests

1. Tropical Wet Evergreen
2. Tropical Semi-Evergreen
3. Tropical Moist Deciduous
4. Littoral and Swamp

B. Dry Tropical Forests

1. Tropical Dry Evergreen
2. Tropical Dry Deciduous
3. Tropical Thorn

C. Montane Sub-tropical Forests

1. Sub-tropical broad leaved hill
2. Sub-tropical moist hill (pine)
3. Sub-tropical dry evergreen

D. Montane Temperate Forests

1. Montane Wet Temperate
2. Himalayan Moist Temperate
3. Himalayan Dry Temperate

E. Alpine Forests

1. Sub-Alpine
2. Moist Alpine scrub
3. Dry Alpine scrub

A. Moist Tropical Forests:

1. **Tropical Wet Evergreen Forests or Rain Forests:**

Climatic Conditions:

Annual rainfall exceeds 250 cm
The annual temperature is about 25°-27°C
The average annual humidity exceeds 77 per cent and The dry season is distinctly short.

Characteristics:

Evergreen: Due to high heat and high humidity, the trees of these forests do not shed their leaves together.

Lofty: The trees often reach 45 – 60 metres in height.

Thick Canopy: From the air, the tropical rain forest appears like a thick canopy of foliage, broken only where it is crossed by large rivers or cleared for cultivation.

All plants struggle upwards (most **ephiphytes**) for sunlight resulting in a peculiar layer arrangement. The entire morphology looks like a green carpet when viewed from above.

EpiphytesLess undergrowth: The sun light cannot reach the ground due to thick canopy. The undergrowth is formed mainly of bamboos, ferns, climbers, orchids, etc.

Distribution:

Western side of the Western Ghats (500 to 1370 metres above sea level).

Some regions in the Purvanchal hills. In the Andaman and Nicobar Islands.

Timber:

1. Hardwood: The timber of these forests is fine-grained, hard and durable.
2. It has high commercial value but it is highly challenging to exploit due **to dense undergrowth, absence of pure stands and lack of transport facilities Plant Species:**

The important species of these forests are **mahogany, mesua, white cedar, jamun, canes, bamboo** etc.

2. Tropical Semi-Evergreen Forests:

They are transitional forests between tropical wet evergreen forests and tropical deciduous forests. They are comparatively drier areas compared to tropical wet evergreen forests.

Climatic Conditions:

Annual rainfall is 200-250 cm

Mean annual temperature varies from 24°C to 27°C

The relative humidity is about 75 per cent

The dry season is not short like in tropical evergreen forests.

Distribution:

Western coast, Assam, Lower slopes of the Eastern Himalayas, Odisha and Andamans.

Characteristics

The semi-evergreen forests are less dense.

They are more **gregarious [living in flocks or colonies – more pure stands]** than the wet evergreen forests.

These forests are characterized by many species.

Trees usually have **buttressed trunks with abundant epiphytes.**

Buttressed Trunks.

Important species: laurel, rosewood, mesua, thorny bamboo – Western Ghats, white cedar, Indian chestnut, champa, mango, etc. – Himalayan region **Timber:**

Hardwood: Similar to that in tropical evergreen forests except that these forests are less dense with **more pure stands**(timber industry here is better than in evergreen forests).

3 Tropical Moist Deciduous Forests:

Climatic Conditions:

1. Annual rainfall 100 to 200 cm.
2. Mean annual temperature of about 27°C
3. The average annual relative humidity of 60 to 75 per cent.

4. Spring (between winter and summer) and summer are dry.

Characteristics;

1. The trees drop their leaves during the spring and early summer when sufficient moisture is not available.
2. The general appearance is bare in extreme summers (April-May).
3. Tropical moist deciduous forests present irregular top storey [25 to 60 m].
4. Heavily buttressed trees and fairly complete undergrowth.
5. These forests occupy a much larger area than the evergreen forests but large tracts under these forests have been cleared for cultivation.

Distribution:

- Belt running along the Western Ghats surrounding the belt of evergreen forests.
- A strip along the Shiwalik range including terai and bhabar from 77° E to 88° E.,Manipur and Mizoram., Hills of eastern Madhya Pradesh and Chhattisgarh., Chota Nagpur Plateau. Most of Odisha. Parts of West Bengal and Andaman and Nicobar islands.

Timber:

- These provide valuable timer like **Teak.**
- The main species found in these forests are teak, sal, laurel, rosewood, amla, jamun, bamboo, etc.
- It is **comparatively easy to exploit these forests due to their high degree of gregariousness (more pure stands).**

4 Littoral and Swamp Forests:

- They can survive and grow both in fresh as well as **brackish water** (The mixture of seawater and fresh water in estuaries is called brackish water and its salinity can range from 0.5 to 35 ppt).
- Occur in and around the deltas, estuaries and creeks prone to **tidal influences (delta or tidal forests).**
- Littoral (relating to or on the shore of the sea or a lake) forests occur at several places along the coast.
- Swamp forests are confined to the deltas of the Ganga, the Mahanadi, the Godavari, the Krishna and the Cauvery.
- Dense mangroves occur all along the coastline in sheltered estuaries, tidal creeks, backwaters, salt marshes and mudflats. It provides useful fuel wood.
- The most pronounced and the densest is the **Sunderban in the Ganga delta** where the predominant species is Sundri (Heriteera).

Timber:

- It provides hard and durable timber which is used for construction, building purposes and making boats.
- The important species found in these forests are Sundri, agar, rhizophora, screw pines, canes and palms, etc.

B **Dry Tropical Forests:**

1. **Tropical Dry Evergreen Forests:**

Distribution:

- Along the coasts of Tamil Nadu.

Climatic Conditions:

- Annual rainfall of 100 cm [mostly from the north-east monsoon winds in October – December].
- Mean annual temperature is about 28°C. The mean humidity is about 75 per cent.
- The growth of evergreen forests in areas of such low rainfall is a bit strange.

Characteristics:

- Short statured trees, up to 12 m high, with complete canopy.
- Bamboos and grasses not conspicuous.
- The important species are jamun, tamarind, neem, etc.
- Most of the land under these forests has been cleared for agriculture or **casuarina plantations.**

Distribution:

- Casuarina is the most popular farm forestry in the states of Andhra Pradesh, Tamil Nadu, West Bengal, Odisha, Maharashtra, Gujarat, and Karnataka.

Benefits:

- Reduces damage in the event of natural calamities.
- Line planting in the coastal areas helps in controlling the wind force.
- It is also used for tourism promotion in view of its ornamental appearance.
- It provides top quality firewood.
- The wood is suitable for paper pulp and useful raw material for the manufacture of paper for writing, printing, and wrapping.
- It is got some serious medicinal values as well.

Wasteland development:

- The characteristics which make it a suitable species for wasteland development include adaptability to wide range of habitats, fast growth, salt tolerant, drought resistant, ability to reclaim land and stabilize sand dunes.
- Intercrops such as groundnut, cucumber, watermelons, sesamum, and pulses can also be raised along with the plantation.

2 **Tropical Dry Deciduous Forests:**

Climatic Conditions:

- Annual rainfall is 100-150 cm.

Characteristics:

- These are similar to moist deciduous forests and shed their leaves in dry season.

- The major difference is that they can grow in areas of comparatively less rainfall.
- They represent a transitional type – moist deciduous on the wetter side and thorn forests on the drier side.
- They have closed but uneven canopy.
- The forests are composed of a mixture of a few species of deciduous trees rising up to a height of 20 metres.
- Undergrowth: Enough light reaches the ground to permit the growth of grass and climbers.

Distribution:

- They occur in an irregular wide strip running from the foot of the Himalayas to Kanniyakumari except in Rajasthan, Western Ghats and West Bengal.
- The important species are teak, axlewood, rosewood, common bamboo, **red sanders**, laurel, satinwood, etc.
- Large tracts of this forest have been cleared for agricultural purposes.
- These forests have suffer from over grazing, fire, etc.

3 **Tropical Thorn Forests:**

Climatic Conditions:

- Annual rainfall less than 75 cm.
- Humidity is less than 50 per cent.
- Mean temperature is 25°-30°C.

Characteristics:

- The trees are low (6 to 10 metres maximum) and widely scattered.
- Acacias and Euphorbias are very prominent.
- The Indian wild date is common. Some grasses also grow in the rainy season.

Distribution:

- Rajasthan, south-western Punjab, western Haryana, Kachchh and neighbouring parts of Saurashtra.
- Here they degenerate into desert type in the Thar desert.
- Such forests also grow on the leeside of the Western Ghats covering large areas of Maharashtra, Karnataka, Telangana, Andhra Pradesh and Tamil Nadu.
- The important species are neem, babul, cactii, etc.

C **Montane Sub-Tropical Forests:**

1. **Sub-tropical Broad-leaved Hill Forests:**

Climatic conditions:

- Mean annual rainfall is 75 cm to 125 cm.
- Average annual temperature is 18°-21°C.
- Humidity is 80 per cent.

Distribution:

- Eastern Himalayas to the east of 88°E longitude at altitudes varying from 1000 to 2000 m.

Characteristics:

- Forests of evergreen species.
- Commonly found species are evergreen oaks, chestnuts, ash, beech, sals and pines.
- Climbers and epiphytes [a plant that grows non-parasitically on a tree or other plant] are common.
- These forests are not so distinct in the southern parts of the country. They occur only in the Nilgiri and Palni hills at 1070-1525 metres above sea level.
- It is a "stunted rain-forest" and is not so luxuriant as the true tropical evergreen.
- The higher parts of the Western Ghats such as Mahabaleshwar, the summits of the Satpura and the Maikal Range, highlands of Bastar and Mt. Abu in the Aravali Range carry sub-types of these forests.

2 **Sub-tropical Moist Pine Forests:**

Distribution;

- Western Himalayas between 73°E and 88°E longitudes at elevations between 1000 to 2000 metres above sea level.
- Some hilly regions of Arunachal Pradesh, Manipur, Naga Hills and Khasi Hills.

Timber:

- **Chir or Chil** is the most dominant tree which forms pure stands.
- It provides **valuable timber** for furniture, boxes and buildings.
- It is also used for producing resin and turpentine.

3 **Sub-tropical Dry Evergreen Forests:**

Distribution:

- Found in the Bhabar, the Shiwaliks and the western Himalayas up to about 1000 metres above sea level.

Climatic Conditions:

- Annual rainfall is 50-100 cm (15 to 25 cm in December-March). The summers are sufficiently hot and winters are very cold.

Characteristics:

- Low scrub forest with small evergreen stunted trees and shrubs.
- Olive, acacia modesta and pistacia are the most predominant species.

D **Montane Temperate Forests:**

1. **Montane Wet Temperate Forests:**

Climatic Conditions:

- Grows at a height of 1800 to 3000 m above sea level
- Mean annual rainfall is 150 cm to 300 cm

- Mean annual temperature is about 11°C to 14°C and the Average relative humidity is over 80 per cent.

Distribution:

- Higher hills of Tamil Nadu and Kerala, in the Eastern Himalayan region.

Characteristics:

- These are closed evergreen forests. Trunks have large girth.
- Branches are clothed with mosses, ferns and other epiphytes.
- The trees rarely achieve a height of more than 6 metres.
- Deodar, Chilauni, Indian chestnut, birch, plum, machilus, cinnamomum, litsea, magnolia, blue pine, oak, hemlock, etc. are important species.

2 **Himalayan Moist Temperate Forests:**

Climatic Conditions:

- Annual rainfall varies from 150 cm to 250 cm **Distribution:**
- Occurs in the temperate zone of the Himalayas between 1500 and 3300 metres.
- Cover the entire length of this mountain range in Kashmir, Himachal Pradesh, Uttarakhand, Darjeeling and Sikkim.

Characteristics:

- Mainly composed of **coniferous species.**
- Species occur in mostly pure strands.
- Trees are 30 to 50 m high.
- Pines, cedars, silver firs, spruce, etc. are most important trees.
- They form high but fairly open forest with shrubby undergrowth including oaks, rhododendrons and some bamboos.

Timber:

It provides fine wood which is of much use for construction, timber and railway sleepers.

3 **Himalayan Dry Temperate Forests:**

Climatic Conditions:

- Precipitation is below 100 cm and is mostly in the form of snow.

Characteristics:

- Coniferous forests with xerophytic shrubs in which deodar, oak, ash, olive, etc are the main trees.

Distribution:

- Such forests are found in the inner dry ranges of the Himalayas where south-west monsoon is very feeble.
- Such areas are in Ladakh, Lahul, Chamba, Kinnaur, Garhwal and Sikkim.

E. **Alpine Forests:**

- Altitudes ranging between 2,900 to 3,500.
- These forests can be divided into: (1) sub-alpine; (2) moist alpine scrub and (3) dry alpine scrub.

1. **Sub-alpine;**

- The sub-alpine forests occur lower alpine scrub and grasslands.

- It is a mixture of coniferous and broad-leaved trees in which the coniferous trees attain a height of about 30 m while the broad leaved trees reach only 10 m. Fir, spruce, rhododendron, etc. are important species.

2. **Moist alpine scrub :**
   - The moist alpine scrub is a low evergreen dense growth of rhododendron, birch etc. which occurs from 3,000 metres and extends upto snowline.
3. **Dry Alpine Scrub:**
   - The dry alpine scrub is the uppermost limit of scrub xerophytic, dwarf shrubs, over 3,500 metres above sea level and found in dry zone. Juniper, honeysuckle, artemesia etc. are important species.

3. Salient features of Indian Forest Policies

India is one of the 12 mega diversity countries having a vast variety of flora and fauna, commands 7% of world's biodiversity and supports 16 major forest types, varying from the alpine pastures in the Himalayas to temperate, sub -tropical forests, and mangroves in the coastal areas.

According to the State of Forest Report, published by the Forest Survey of India (FSI) in 1997, India has a recorded forest **area of 76.5 million hectare or 23.3%** of the total geographic area of the country. But the actual forest cover is **63.34 million ha (19.27% of the country's area)** of which **26.13 million ha are degraded**. There is another **5.72 million ha scrub** in addition to the reported forest cover of 63.34 million ha. Thus, in total, **31.85 million ha forests** in the country are degraded or open.

Comparison with other countries

The area of the world's forests, including natural forests and forest plantations, was estimated to be **3454 million hectares in 1995**, or about one-fourth of the land area of the Earth.

About **55 percent of the world's forests** are located in **developing countries**, with the remaining **45 percent in developed countries**. The world's forests are almost equally divided between tropical/subtropical forests and temperate/boreal forests.

Only about **3 percent of the world's forests** are forest plantations. The remaining **97 percent are natural or semi-natural forests.**

Genesis of Forest Policies in India

Traditionally, life styles of the people in India have been environment friendly and conducive to protection and conservation of forests.

The customs and religious philosophy of nature worship, sacred groves, tree and animal worship and festivals related to nature and seasons bear testimony to the fact that the traditions laid down by the religious and social leaders were environment friendly (FAO,1997).

Due to multiple value and use of forest resources people in the past lived in synergy with nature and its resources and hence, the need for forest management was not felt so strongly as in present times.

The earliest evidence of forest management by the State is found in Kautilaya's Arthashastra (321 B.C) indicating that forests were managed as State Reserves for revenue and *"LOKAVAM"* (Public Forests) for public use (Country Report India, 1994).

Before 1850, shifting cultivation was a common practice and it was sustainable with a small population. However, by 1850 the population had increased to 200 million the pressure on forests had begun to be felt. The British rule continued with the earlier practice of declaring certain tree species as property of the Government for the collection of royalty and leaving the rest of the area to be used freely by the people (Shyam Sunder, 1992).

It was in 1864 when Brandis was appointed as the first Inspector General of Forests of India, the foundation of scientific and organized forestry was laid (GOI, 1999). In 1864 the Forest Department was established and a regular forest service began to function. However, the first regular policy statement relating to forestry was issued in 1894 based on Voeleker's Report on the improvement of Indian Agriculture.

The report provided guidelines for the management of government forests in India and underlined that public benefit would be the sole objectives for the State administration of forests. The satisfaction of people's needs was a priority, more important than the realization of revenue through felling of trees. Yield of timber by felling trees was regulated based on the fundamental principle of sustainability. Further, forests that yielded only inferior timber, fuel wood or fodder, or used for grazing, were to be managed mainly in the interest of local people (MoEF, 1999).

This was followed by the creation of a separate forest service and adoption of legal measures like the 1865 Forest Act which was revised in 1878 to confer powers to the newly constituted Forest Departments.

It recommended the creation of different categories of forests as 'reserved' and 'protected' forests. The payment of compensation was to be made for the rights over reserved forests whereas; the rights over the protected forests were to be regulated through settlement reports. The scientific management of forests led to the concepts of working plans and management units as divisions and circles for the forest management in different States.

In 1889, the Government of India invited Dr J.A. Volecker to examine the condition of agriculture including forestry (Bhumbla, 1992).

The report was submitted in 1893 providing guidelines for management of forests in India in which the public benefits was underlined to be the sole objective for the administration of forests.

Forest Policy of 1894

In 1894, a resolution on the forest policy was made for the first time and the first Forest Policy was enunciated (GOI, 1976). India's first Forest Policy in 1894 sought to provide guidelines towards uniformity in management of government forests over the entire country. The policy laid down 'Public Benefit' as the sole objective of the administration of public forests. With reference to their primary functions, the government owned /public forest was classified as follows (FAO, 1993):

1. Forests, the preservation of which was essential on climatic or physical ground which fulfill the benefit of the community.
2. Forests that supply valuable timber for commercial purposes.
3. Minor forests which produced only inferior timber and fuel wood.
4. Pasture lands.

The forest policy of 1894 provided the following guidelines:

1. The sole objective to which the management of forests is to be directed is to promote the Public Benefit.
2. The preservation of forests involves regulating the rights and restricting the privileges of users in the forest areas.
3. Forests that yield only inferior timber, fuelwood, fodder or used for grazing should be managed only in the interest of people.
4. The *maintenance of adequate forests is dictated primarily for the preservation of* the climate and physical conditions of the country

Forest Policy: Need for Reorientation

- The colonial impact on the natural forests and environment was colossal and devastating.
- The methods and the forest management practices were wasteful, and destructive (Pouchepadass, 1995).
- This was on account of the quest for more revenue and the insatiable demand for timber by the railways and military in the economy (Nair, 1985).
- Thus, after independence in 1947, it was felt that "the revolutionary changes which have taken place during the interval in physical, economic and political fields, called for a reorientation of the old forest policy (Maslekar, 1983).
- During the beginning of the twentieth century, far reaching developments in the economic, social and political fields, took place in the country.
- In addition, India passed through two world wars (Ministry of Food and Agriculture, 1952) which also had serious repercussions on forests in terms of heavy deforestation in order to meet the defense needs.
- build ships and railway sleepers, gaining maximum revenue from the forests,

- In addition, to the impact of the two World Wars, a large slaughter of wild animals (Elliott, 1973) and the conversion of large expansions of the forest woodlands into tea, coffee and rubber plantations by the British business houses (Sinha, 1986), were the other reasons for forest degradation during the colonial period.
- After these destructive circumstances, the Government of India soon after the independence realized the role of forests in maintaining ecological balance through the prevention soil erosion.
- Apart from this, the importance of forests in the agriculture industries, defense, commerce, construction and other developmental activities was also realized.
- It becomes clear from the statement of FAO (1952) in the context of the formulation of the Forest Policy of 1952 'it would be a mistake to attribute this new orientation only to political change in India since 1894'.

National Forest Policy, 1952

This was the first Forest Policy declared by the Government of Independent India.

This policy of 1952 substantially removed the deficiencies in the earlier policy. The policy for the first time recognized the protective role of forests and discarded the notion that forestry has no intrinsic right to land.

The policy stated that the nation as a whole had a vast stake in the conservation of forests and also identified the degradations of forests caused by the indiscriminate extension of agriculture during the British rule

The Forest Policy of 1952 retained the fundamental concept underlined in the old policy, but considered six paramount needs of the country in its formation (Ministry of Food and Agriculture, 1952).

These needs were:

1. The need for evolving a system of balanced and complementary land use, under which each type of land is allotted to that form of use under which it would produce most and deteriorate least.
2. The need for checking:
    a) Denudation of mountainous regions, on which depends the perennial water supply of river system whose basins constitute the fertile core of the country.
    b) The erosion progressing pace along treeless banks of the great rivers leading to ravine formation and on vast stretches of undulating wastelands depriving the adjoining fields of their fertility.
    c) The invasion of sea-sands of coastal tracts, and the shifting sand dunes, more particularly in *Rajputana* deserts.
3. The need for establishing tree lands, where whenever possible for the amelioration of physical and climatic conditions promoting the general wellbeing of people.

4. The need for progressively increasing supplies of grazing, small wood for agricultural implements and in particular of firewood to release the cattle dung for manure to step up food production.
5. The need for sustained supply of timber and other forest produce required for defense, communications and industry.
6. The need for the realization of the maximum amount of revenue in perpetuity consistent with the fulfillment of the needs.

Hence, to facilitate fixing of priorities in management, the policy indicated the following functional classification of forests:

I. **Protected Forests:** Those forests which must be preserved or created for physical and climatic considerations.

II. **National Forests:** Those which have to be maintained and managed to meet the needs of defense, communications, industries and other general purposes of public importance.

III. **Village Forests:** Those forests which have to be maintained to provide firewood, small timber and other forest produce for local requirements, and to provide grazing for cattle.

IV. **Tree Lands:** Those areas which though outside the scope of forest management are essential for the amelioration of the climatic and physical condition of the country. **The salient features of the policy**

1. The policy discarded the notion that the forestry as such had no intrinsic right on land and rejected the belief that forestry should be restricted to residual lands not required for any other purposes.
2. The policy for the first time laid stress on having at least one third of the land area under forest cover and the need for wild life conservation. The percentage was determined to be at 60 per cent for the hill regions and 20 per cent for the plains. However, its main focus remained on sustainable timber production, without much emphasis on management of non commercial species and non wood forest products.
3. This policy also stated the need for checking denudation on the hills, soil erosion and invasion of sand from deserts and coastal areas. The establishment of tree lands to ameliorate conditions and promote well being of the people and to maximize annual revenue in perpetuity consistent with the fulfilment of all the other conditions was also stated.
4. Controlling grazing in forest areas and it should be regulated.
5. Awakening the interest of people in planting trees.

National Forest Policy, 1952: An Analysis

The National Forest Policy of 1952, which retained the fundamental concepts underlying the previous policy, unfortunately remained almost unimplemented. Most of the policy provisions could not be implemented due to the problems like chronic food shortages and rapid expansion in human as well as livestock population (Bahuguna 2000).

The National Commission on Agriculture (NCA, 1976) appointed by the government to examine all aspects of agriculture including forestry contained clear indications that most of the principles and policy measures outlined in the policy were not implemented or implemented effectively. NCA pointed out the following reasons for this failure of the policy measures (NFAP, (1999):

1. Administration of forests vested entirely with the states. They were ultimate authority to implement a policy decision.
2. The provisions in the policy were not fully implemented by the states.
3. Functional classification of forests could not be implemented.
4. No systematic programme was drawn up to extend existing tree lands and to establish the new ones.
5. No concrete efforts were made to bring the recommended percentage of area under forests cover.
6. Hardly any of the principles of forests grazing was implemented.

Keeping in view the above mentioned changes in Indian forestry, the Prime Minister, in the meeting of the Central Board of Forestry (1987) for the first time, stressed the need for effective people's participation in forest protection in his address.

It resulted in the revision of forest policy in India and the new National Forest Policy was enunciated in 1988.

Forest Policy of 1988

The first National Forest Policy of Independent India was promulgated in 1952. However, since then many new developments had taken place and concepts of forest management changed. It was in view of the following perspectives, the need of a new forest policy was felt.

The emphasis was gradually shifting from production forestry to conversion and protection of the forest resources.

The needs and attributes of the general masses with regard to forests and forestry had undergone a massive change

1. Many new forest based industries were being set up and it was apparent that their raw material requirements could not be met from the natural forests, without upsetting the ecological balance.
2. Social community and farm forestry had gained increasing importance in the seventies and eighties.
3. There was a need to address the rights and concessions of the people and recognize the symbiotic relationship between forests and tribals.
4. Provisions needed to be incorporated in the forest policy for ecological security, biodiversity conservation and compensatory afforestation.

The National Forest Policy of 1988 was issued on 7th December 1988 by the Secretary, Ministry of Environment and Forests to the Government of India.

BASIC OBJECTIVES

1. Maintenance of environmental stability through preservation and, where necessary, restoration of the ecological balance that has been adversely disturbed by serious depletion of the forests of the country.
2. Conserving the natural heritage of the country by preserving the remaining natural forests with the vast variety of flora and fauna, which represent the remarkable biological diversity and genetic resources of the country.
3. Checking soil erosion and denudation in the catchment areas of rivers, lakes, reservoirs in the interest of soil and water conservation, for mitigating food and droughts and for the retardation of siltation of reservoirs.
4. Checking the extension of sand dunes in the desert areas of Rajasthan and along the coastal tracts.
5. Increasingly substantially the forests/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands.
6. Meeting the requirements of fuel wood, fodder, minor forest produce and small timber of the rural and tribal population.
7. Increasing the productivity of forests to meet essential national needs.
8. Encouraging efficient utilisation of forests produce and maximising substitution of wood.
9. Creating a massive people's movement with the involvement of women, for achieving these objectives and to minimise pressure on existing forests.

4.

Natural regeneration - natural regeneration from seed and vegetative parts, coppicing, pollarding, root suckers with examples.

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.

Natural Regeneration of Forest

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

I) **Natural Regeneration from Seed**
II) **Natural Regeneration by Coppice and Root Suckers**
III) **Natural Regeneration by Root Suckers**

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

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

Coppice System of Silviculture

Defined as that Silviculture System in which the new crop originates mainly from shoot / stool coppice and where the rotation of the coppice is short. **Various Methods of Coppice System are followed as**

1) Simple Coppice
2) The Coppice of Two Rotations System
3) Sheltered Coppice
4) Coppice with Standard Systems
5) Coppice with Reserves System 6) Coppice Selection System 7) The Pollard System.

1) Simple Coppice: Defines as Silviculture System based on stool coppice, in which the old crop is, clear filled completely with no reservation for sheltered wood or any other purpose.

Advantages of Simple Coppice:

1) Very simple / no skill
2) Regeneration is more certain
3) Grows fast - so cost of weeding / cleaning and protection is less,
4) Reduces rotation period as growth is very fast 5) Net returns are more even small sized wood produced **Disadvantages of Simple Coppice:**

1) Small sized low price timber
2) Exhaust more mineral substances as more shoots produced
3) Not permanent / after every coppice some shoots dies
4) Great damage by frost and wind
5) Not desirable from aesthetic point of view

2) Coppice of Two Rotations Systems: Modification of Simple coppice system which at the end of the first rotation of coppice, a few selected poles are left scattered singly over the coupe in the second rotation to attain bigger size.

3) The Sheltered Wood Coppice System: Another modification on Simple coppice system in this system even in the first clear felling, some sheltered (125 to 150 trees/ha) trees are retained for frost protection.

Applied in Following Circumstances:

1) Where forest is of common occurrence 2)
Where locality is good.
3) Where the species to be worked can coppice up to a longer age.
4) Where in addition to small sized timber, demand for large timber also.
5) Where a rotation longer.

4) Coppice with Standards: Defined as Silviculture System. based on coppice in which an over wood of standards usually seedlings origin and composed of trees of various ages as kept over coppice for periods which may be multiples of coppice rotation and a permanent feature of the crop throughout two peculiarities which differentiate it from the simple coppice.

5) Coppice with Reserves: Felling is done only in suitable areas likely to benefit, after reserving all financially immature growth of principal as well as other valuable miscellaneous species, either singly or in optimally spaced groups, tree yielding products of economic importance and entire crop for protective reasons.

6) Coppice Selection System: Silviculture System in which felling is carried out on the principles of selection system but regeneration is obtained by coppice.

7) The Pollard System: Pollard is defined as a tree whose stem has been cut off in order to obtain a flush of shoots, usually above the height to which the browsing animals can reach. Thus, the Pollard system consists in Pollarding trees periodically to obtain exploitable material.

5. Artificial regeneration – objectives, choice between natural and artificial regeneration, essential preliminary considerations for AR

Regeneration by Artificial Method

Definition: artificial regeneration is defined as 'the renewal of forest crop by sowing, planting or other 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.

Objectives:

1. Afforestation:
   Establishing a forest by artificial means on an area on which not forest vegetation has existed for a long time in the past

2. 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.

Choice between natural and artificial regeneration

1. Risk of loss and determination of soil
2. Crop composition
3. Genetic consideration
4. Risk damage by pest
5. Flexibility of operation
6. Density of stocking
7. Yield
8. Time factor
9. Cost

Why we go natural regeneration to artificial regeneration:
1. Quality planting stock
2. More production
3. Meet the industrial demand
4. Assumed planting stock
5. Resistant varieties
6. Reduced rotation age

7. Multiple suitable species
8. Clonal propagation
9. Timing silvicultural operation

Essential preliminary considerations for AR or Basic Steps in Artificial Regeneration:

1. Choice of species 2. Site selection 3. Choice of method i. Sowing ii. Planting iii. Cutting

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 deltoides 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) 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 desirabl species.

4) Man Power and Equipment: The site selection and preparation methods require good skil 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.

3) 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
ii) Planting/ planting.
iii) Cutting

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

iii) Cutting or 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.

Advantages of artificial regeneration method

1. Controlled plant density 2. Predictable seedling production 3. High flexibility 4. Low management intensity 5. Option of introducing improved seed or plant material 6. Changing species and or varieties

Disadvantages of **artificial regeneration method**

1. Labour intensive 2. Temporarily disturbed root development 3. Less adopted to microsite 4. Cost intensive

6. Crown classification of trees

Crown class **is a term used to describe the position of an individual tree in the forest canopy.**
In the definitions below, "general layer of the canopy" refers to the bulk of the tree crowns in the size class or cohort being examined.

Crown classes are most easily determined in evenaged stands, as depicted in Figure 6.1. In an unevenaged stand, a tree's crown would be compared to other trees in the same layer. Kraft's Crown Classes are defined as follows (Smith et al. 1997 and Helms 1998 modified for clarity):

- **Dominant trees** These crowns extend above the general level of the canopy. They receive full light from above and some light from the sides. Generally, they have the largest, fullest crowns in the stand (Figure 6.5).
- **Codominant trees** These crowns make up the general level of the canopy. They receive direct light from above, but little or no light from the sides. Generally they are shorter than the dominant trees.
- **Intermediate trees** These crowns occupy a subordinate position in the canopy. They receive some direct light from above, but no direct light from the sides. Crowns are generally narrow and/or one-sided, and shorter than the dominant and codominant trees.
- **Suppressed trees (Overtopped trees)** These crowns are below the general level of the canopy. They receive no direct light. Crowns are generally short, sparse, and narrow.

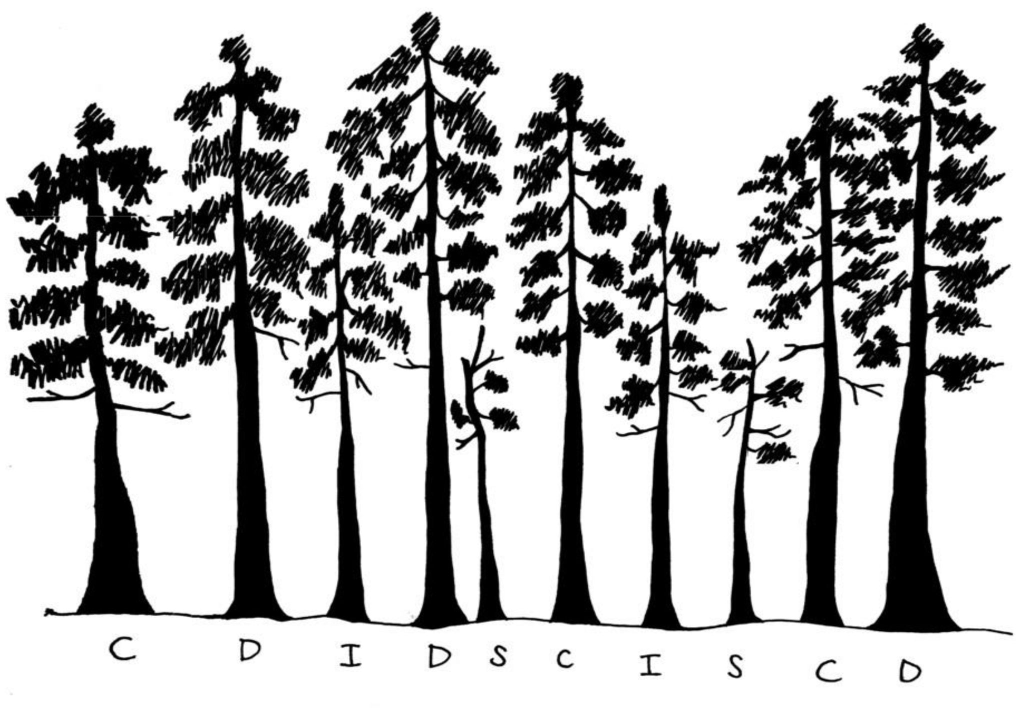


Figure 6.1. An illustration of crown classes. "D" = Dominant; "C" = Codominant; "I" = Intermediate and "S" = Suppressed.

Crown classes are a function of tree vigor, tree growing space, and access to sunlight. These in turn are influenced by stand density and species shade tolerance. A "suppressed" Douglas-fir tree is likely of low vigor and will probably die out. It typically would not be able to respond to an increase in sunlight if a neighboring tree fell over. A shade tolerant "suppressed" western hemlock on the other hand, may survive very nicely and be able to take advantage of increased sunlight if a neighboring tree were to fall over.

Crown class distribution can also infer overall vigor of an evenaged stand. If most trees are in the intermediate crown class, then the stand is likely too crowded and the trees are stagnated. A stand with nearly every tree in the dominant category is either very young, with all of the trees receiving plenty of sun, or very sparse and may be considered "understocked." A typical evenaged stand has the majority of trees in the codominant class, and the fewest trees in the suppressed class. The relative ratios of dominant and intermediate classes are generally a function of species composition. Examine the data in Figure 6.2 and Table 5.3 below.

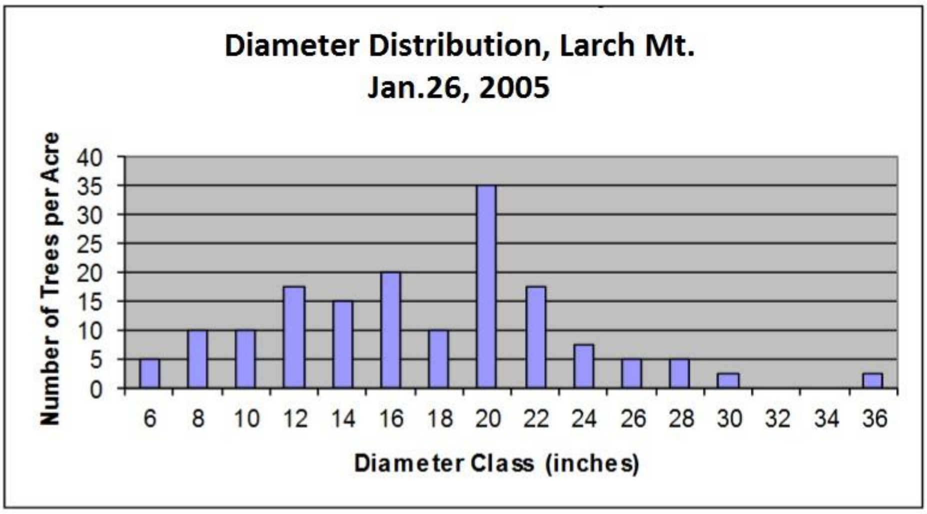


Figure 6.2. Diameter classes of an evenaged stand near Larch Mountain, OR. Source: Data collected by Mt. Hood Community College Forest Measurements I class on January 26, 2005.

This 60 year-old stand of primarily Douglas-fir and western hemlock, displays a bell-shaped diameter distribution, characteristic of an evenaged stand. Most of the trees are clustered around the average DBH, with some smaller and some larger than the center range.

Table 5.3. Percent of each Species by Crown Class. Source: Data collected in evenaged stand near Larch Mt. by Mt. Hood Community College Forest Measurements I class in January, 2005.

Species	Dominant	Codominant	Intermediate	Suppressed
	29% of all trees measured	35% of all trees measured	24% of all trees measured	13% of all trees measured
Douglas-fir	67	64	40	12
Western hemlock	33	36	60	88

Note that the majority of trees are in the codominant crown class (35% of all trees), which is typical of an evenaged stand. These trees most likely make up the bulk of the 16“““-22” diameter classes. It is interesting to examine the species composition data. The majority of dominant and codominant trees are Douglas-fir, while the intermediate and suppressed trees are primarily shade tolerant western hemlock. Therefore, healthy trees in the small diameter classes (6-10 inches) may survive over time, even though they are surrounded by large trees. Crown class by itself does always reflect vigor; there is another element to examine besides position in the crown.

7.
Tending operations – weeding, cleaning, thinning – mechanical, ordinary, crown and advance thinning

Tending Operations in Silviculture

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.

Objectives of Tending Operation - Thinning

1) To Improve the Hygiene of the Crop:

By removing dead, dying and diseased trees, hygiene or health of tree can be maintained well.

2) Salvage of Anticipated Losses of the Merchantable Volume:

A large number of trees die of suppression. This amount contributes of about 20 per cent of the merchantable volume. Thinning contributes a substantial amount in the total yield of crop. Thinning helps in shortening of the rotation. Reduction in number of trees in thinning increases the diameter of the remaining trees.

3) To assure the Best Physical Conditions of Growth:

The objective of the thinning is to keep growing stock somewhere within the range. The effect of extreme competition is reflecting by decline in the rate of growth with increasing density in crops which are very dense. Thinning increase the diameter of the crops. Thus thinning may be essential tool for shortening the rotation of a crop.

4) To Obtain Desired Crop:

Thinning helps to improve the stand structure. It ensures a uniform and proper distribution of trees all over the area. This enables the trees to tap water and nutrients from a larger area. The composition of the crop can also be improved. The less valuable species may be removed in thinning and the important and valuable species may be retained for future. **5) Improvement of Stand Composition, Regeneration and Protection:**

If an undesirable species is not eliminated during regeneration stage it can be done during thinning to a certain extent. Thinning helps in obtaining suitable seed bearers for obtaining successful regeneration. The dead, drying and diseased trees are removed to afford protection from insect pest, disease and fire because these trees may serve as a source of infection.

6) Improvement in Wood Quality:

Thinning may also improve the quality of wood because trees with higher diameter are likely to be of better quality than smaller ones.

7) To Increase Net Yield and Financial out turn from a Stand:

Thinning help to obtain returns early. The sale of thinning material helps to reduce investment burden because of early returns from thinning and shortening of rotation.

8) To Help Decomposition of Raw Humus:

In temperate forests, thinning increases light and temperature on the forest floor and causes mechanical disturbance which help the decomposition of raw humus and release of nutrients, etc.

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.

Factors Affecting Tending Operation Thinning Practices

The following factors are important for deciding the adoption of thinning practice. **i)**

Nature of Species:

Light demanders are less tolerant of crowding than shade bearers and therefore, frequent thinning is required to remove competition in light demander species.

ii) Age:
In young age, when the crown formation has not completed, mechanical thinning or stick thinning by some numerical formula is carried out with success.

iii) Site Quality:
On poor sites, heavy thinning is not recommended because the rate of growth on such sites is poor and the heavy openings may not be occupied.

iv) Improvements in Felling:
Improvement felling has been defined as per removal of less valuable trees in a crop with the interest of better growth of the more valuable individuals, usually applied to a mixed, uneven aged forest. It may include thinning of closely stoked groups along with clearing and general assistance to young growth of valuable species.

v) Pruning:
Pruning is defined as the elimination of branches in order to obtain trees with clean bole. The elimination of branches by physical and biotic agencies of the environment is called Natural pruning. Removal of branches from the selected portions of the tree by mechanical means is referred as artificial pruning. Pruning occurs naturally when the crop is dense enough particularly in younger stage. The process of natural pruning completes in three stages namely:

i) Killing of branches, ii) Shedding of dead branches and iii) Halting over of the entire branch stub

Killing of the branches is determined by the density of the crop. The lower branches of trees usually die when crows of the adjacent trees are close to each other. Death in such cases occurs below the point of closer. The shading of branches occurs after the dead branches are attacked by saprophytic fungi, insects, etc. are broken away by winds etc. The shading of dead branches from the main stem is followed by the occlusion of the short stubs produced by the dead branches. Natural pruning can be accelerated by manipulation of the density and composition of the crop. The rate of killing of lower branches, their shedding and healing of the branch stub depends on species and their habitat factors. The retention of under story trees may also lead to effective natural pruning. The simplest method of obtaining natural pruning is to develop and maintain dense stocking in the main crop. This may decrease the rate of diameter increment. Therefore, it is necessary to reduce the crop density as soon as natural pruning is achieved.

Artificial pruning results in production of clear boled trees on shorter rotation than would be required in natural pruning. Plantation cannot be raised in closer spacing because it leads to higher investment and therefore artificial pruning, sometimes may be necessary.

In the artificial pruning, the moribund and lower green branches are cut off from the main stem as near to the bole as possible. The use of handsaw has been found useful than bladed instruments. A small ladder is also necessary. Except in certain cases e.g. poplar, mulberry, artificial pruning on large scale has yet to be adopted in India. The height up to which pruning should be carried out artificially depends upon species, age and local conditions. In young plantations it should be carried out up to one half to three fifth of the total height of the tree. The object of pruning is to obtain knot free timber and it is likely to be obtained more effectively by the removal of lateral buds.

vi) Climber Cutting:

Climber cutting should be done along with the tending operations as well as while carrying out markings for felling in the forest. Climbers are particularly harmful when the trees are young. In older trees, they constrict the stem and deteriorate the value of wood.

The climber cutting should be done at the base and one meter above and the piece should be removed in order to ensure that climber has been cut. A more effective method for the control of climber is to dig up tubers during the rains. The climbers should be cut preferably during monsoon.

Lect. 8

Definition and Scope of Forest Mensuration

- An area set a side for the production of timber and other forest produce.
- A plant community predominantly of trees and other woody vegetation usually with a closed canopy (Glossary).

Mensuration

- It means measurement of length, mass and time etc.
- Is art and science of locating, measuring and calculating the length of lines, areas of planes, and volumes of solids.
- Forest Mensuration deals with the determination of the volume of logs, trees, and stands, and with the study of increment and yield (Graves, 1906).
- Forest Mensuration is the determination of dimensions, form, weight, growth, and age of trees individually or collectively, and of the dimensions of their products (Helms, 1998).
- It is a tool that provides facts about the forest crops or individual trees to sellers, buyers, planners, managers and researchers.

Objectives

- Provide quantitative information regarding forest resources that will allow making reasonable decisions on its density, use and management.

Forest mensuration serves the following objects

- Basis for sale
- Basis for management
- Measurement for research
- Measurement for planning

Scope

Branch of forestry which provides foundations of measurement principles applicable to any forest management problems.

- Has a wide scope.
- involves all stakeholders i.e. Labors, buyers, sellers, contractors, planners, managers/foresters and researchers.
- applicable to any forest measurement problems of wildlife management, watershed management, insect and disease incidence, recreation, tourism and in fact, many of the mensurational aspects of multiple use forestry.

Importance of Forest Mensuration

It is the keystone foundation of forestry.

- What Silvicultural treatment will result in best regeneration and growth?
- What species is most suitable for reforestation?
- Is there sufficient timber to supply a forest industry and for an economical harvesting operation?
- What is the value of the timber and land?
- What is the recreational potential?
- What is the wildlife potential?
- What is the status of biodiversity on the area?
- What is the status of the forest as a carbon sink?
- What is in the forest now?
- How is the forest changing?
- What can we do to manage the forest properly?
- How can it be assessed?
- And for what purpose?

It helps to answer all these questions and concepts involved in forest management.

- "You can't efficiently make, manage, or study anything you don't locate and measure".
- Forest mensuration is the application of measurement principles to obtain quantifiable information for forest management decision making.

Scale of Measurement

- Nominal Scale: determination of equality (numbering and counting). Eg. numbering of forest types in a stand map.
- Ordinal scale: determination of greater or less (ranking) eg. timber and log grading.
- Interval scale: determination of the equality of intervals or of differences (numerical magnitude of qty, arbitrary origin) eg. Fahrenheit temp., soil moisture etc.
- Ratio scale: determination of equality of ratios (numerical magnitude of qty., absolute origin) eg. length of objects, volumes, etc.

Bias, Accuracy and Precision Bias

- refers to the systematic errors that may result from faulty measurement procedures, instrumental errors, flaws in the sampling procedure, errors in the computations, mistakes in recording, and so on.

Accuracy

- is the closeness of a measurement to the true value
- Success of estimating the true value of a qty.
- refers to the size of the deviation of a simple estimate from the true population

Precision

- means the degree of agreement in a series of measurements.
- is the closeness of a measurement to the average value.
- Refers to the deviation of sample values about their mean.

Relationship among Accuracy (A), Bias (B) and Precision (P).

- $A^2 = B^2 + P^2$

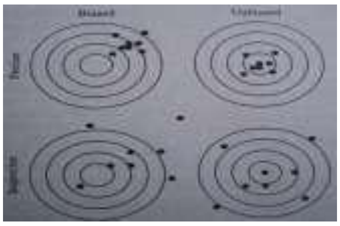


Fig. Precision, Bias and Accuracy. The target's bull's eye is analogous to the unknown true population parameter and the holes represent parameter estimates based on different samples.
The goal is accuracy, which is the precise, unbiased target.

2.1.1 Diameter measurement and its significance

- A diameter is a straight line passing through the center of a circle or sphere and meeting at each end of circumference or surface.
- The most common diameter measurements taken in forestry are of the main stem of standing trees, cut portions of trees and branches.
- Diameter measurement is important because it is one of the directly measurable dimensions from which tree cross sectional area, surface area and volume can be computed.
- The point at which diameters are measured will vary with circumstances.
- The most frequent tree measurement made by forester is diameter at breast height (dbh).
- DBH is defined as the average stem diameter outside bark, at a point 1.3 m above ground as measured
- The rational of DBH measurement of individual trees is to estimate the quantity of timber, fuel wood or any other forest products which can be obtained from them.
- DBH is important variable to calculate the product quantity.

- These measurement are also necessary for making inventory of growing stock as well as to correlate height, volume, age, increment with most easily determinable dimension i.e. dbh

DBH has been accepted as the standard height for diameter measurement because …

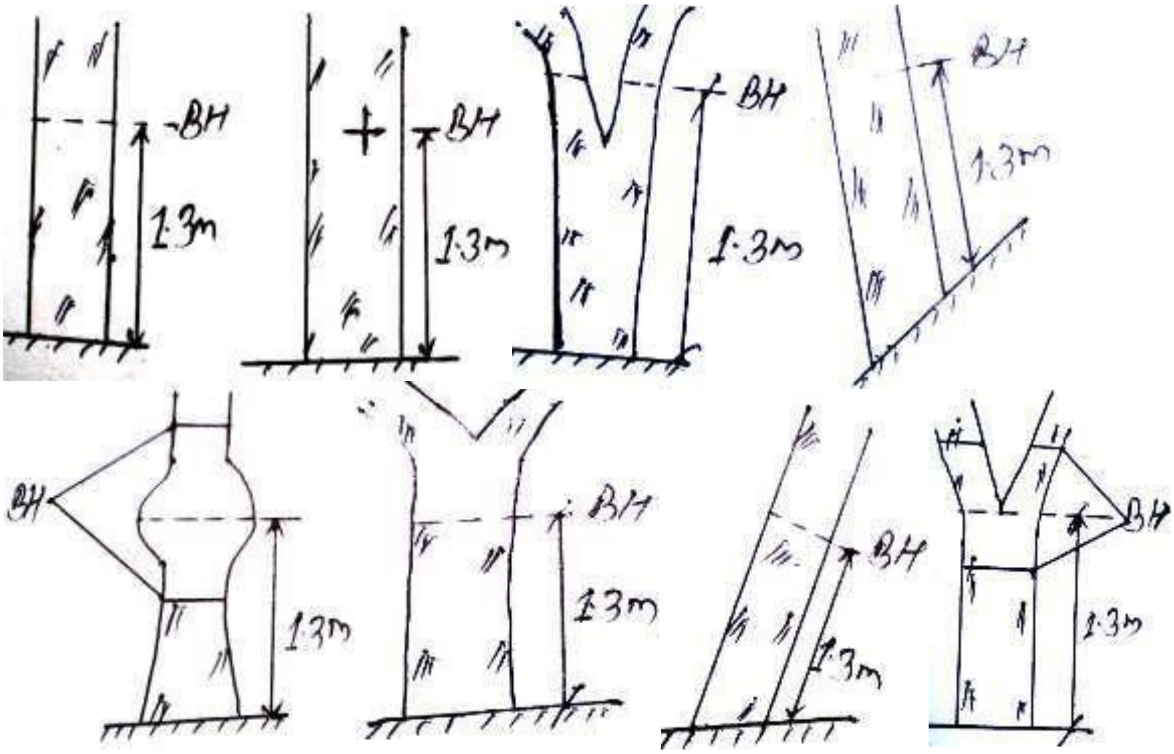
- It is a convenient height for taking measurements and therefore avoids the fatigue unnecessarily caused in taking large number of measurement at any other lower or higher point.
- The base of the tree is generally covered with the grasses and shrubs and even thorns sometimes and so the measurement of diameter or girth at the base is generally very difficult without incurring extra expenditure in clearing the base.
- Majority of the trees develop root swell near the base. This results in abnormal formation from ground level to a certain height along the bole. These abnormalities depend upon the species and the conditions of the ground on which the tree grows. However, in most cases, the abnormalities disappear below breast height.
- It gives a uniform point of measurement and therefore standardizes diameter measurements of trees.
- It is preferred to diameter measurement at stump height because stumps are never cut at uniform height and as such standardization is lost. The height of stump also depends upon the skill of the labor and the commercial value of the trees.
- Even if the stump height is standarized the value of such diameter or girth measurement is completely upset by a change in utilization standards demanding either higher or lower stump.

2.1.2 Rules of DBH measurement and instrument used

Rules of DBH measurement

- Moss, creepers, lichens and loose bark found on the tree must be removed before measuring the dia. over bark.
- Breast height (BH) should be by means of a measuring stick on standing trees at 1.3m above the ground level.
- BH point should be marked by intersecting vertical and horizontal lines 12 cm long, painted with white paint.
- On sloping land, the diameter at BH should be measured on the uphill side.
- In case of the tree is leaning, dbh is measured along the tree stem and not vertically, on the side of the lean for trees growing on flat ground and on the uphill side, for trees growing on sloping ground.
- The dbh should not be measured at 1.3m if the stem is abnormal at the level. BH mark should be shifted up or down as little as possible to a more normal position of the stem and then dia. Measured.
- BH should be taken at the lowest point above which the buttress formation is not likely to extend

When the tree is forked above the BH, it is counted as one tree, but when it is forked below BH, each fork should be treated as though it were a separate tree.



Instrument used in diameter measurement

- The most commonly used instruments for measuring diameters at BH are: Diameter tape, calipers, Biltmore stick, Sector Fork and other optical instruments.

Diameter tape

- The diameter of a tree cross section may be obtained with a flexible tape by measuring the circumference of the tree and dividing by π(D=C/ π). The diameter tapes used by foresters, however are graduated at intervals of π units (in or cms), thus permitting a direct reading of diameter. A diameter tape is a measuring tape that has scales on both sides: one side is specially marked to show the diameter of a tree, and the other is a normal scale.

To measure diameter using a diameter tape:

- Wrap the diameter tape around the tree at the required height, ensuring that the tape is not twisted and the correct scale is visible.
- Make sure the tape is held tightly around the tree and at right angles to the main stem, and
- Read the tree diameter from the tape and record to the nearest 0.1cm
- Care must be taken that the tape is correctly positioned at the point of measurement that it is kept in a plane perpendicular to the axis of the stem, and that it is set firmly around the tree trunk.
- These tapes are accurate only for trees that are circular in cross section.
- The diameter tape is convenient to carry and in the case of irregular trees, requires only one measurement.

Calipers

- Calipers are often used to measure tree dbh or when diameters are less than about 60 cm. calipers of sufficient size to measure large trees, or those with high buttresses are awkward to carry and handle, and particularly in dense undergrowth.
- A calipers may be constructed of metal, plastic or wood, consists of a graduated beam/rule with two perpendicular arms. One arm is fixed at the origin of the scale and the other arm slides. When the beam is pressed against the tree and the arms closed, the beam of the caliper can be read on the scale.

- For an accurate reading, the beam of the caliper must be pressed firmly against the tree with the beam perpendicular to the axis of the tree stem and the arms parallel and perpendicular to the beam.

To use calipers to measure diameter:

- Place the calipers over the stem at the required height. Ensure they are held level with the stem and close them gently. Do not apply excess pressure to the calipers as this will compress the bark, resulting in an incorrect measurement.
- Record the diameter then take another measurement at a right angle to the first and record this measurement and
- Calculate the average of the two measurements and record to the nearest to 0.1cm. These are generally less precise than a diameter tape but may be quicker to use, particularly for small trees, and can take into account some degree of stem eccentricity.

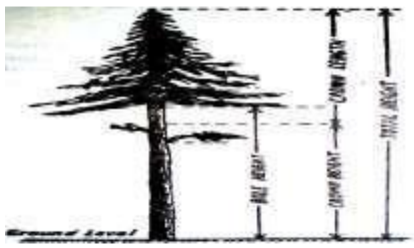
Measurement of upper stem diameters

- Tree stem diameters above breast height are often required to estimate form or taper and to compute the volume of sample trees from the measurement of diameters at several points along the stem.
- Diameter measurement can be made at the desired points on the stem after tree felling or by climbing a tree.
- Instruments for measuring stem diameters of standing trees allow diameters to be determined from the ground at some distance from a tree.
- Some instruments are: Barr and stroud dendrometer, the wheeler pentaprism, the speigel relaskop etc.

LECT- 09 Measurement of Trees Height

Height Measurement

- Height is the linear distance of an object normal to the surface of the earth.
- Tree height is the vertical distance measured from the ground surface.
- Height of standing tree is measured to find out its volume. Height of selected trees in a forest are also required to read volume tables, form factor tables, yield tables etc.
- Lastly, heights of trees are required to find out productive capacity of site. Height is generally considered as an index of fertility and with the knowledge of age it gives a reliable measure of the site quality of a locality.
- **Total height** of a standing tree is the distance along the axis of the tree stem between the ground and the tip of the tree.
- **Bole height** is the distance along the axis of tree between ground level and crown point. (crown point is the position of the first crown forming branch).
- **Commercial bole height** is the height of bole that is usually fit for utilization as timber.
- **Height of standard timber bole** is the height of the bole from the ground level up to the point where average diameter over bark is 20cm.
- **Stump height** is the distance between the ground and basal position on the main stem where a tree is cut.
- **Crown length** -The vertical measurement of the crown of the tree from the tip to the point half way between the lowest green branches forming green crown all round and the lowest green branch on the bole.
- **crown height -** The height of the crown as a measured vertically from the ground level to the point half way between the lowest green the lowest green branches forming green crown all round.

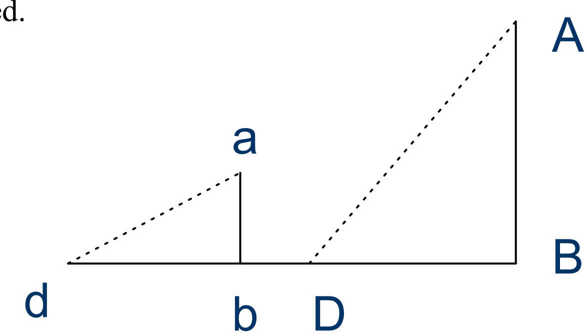


Methods of Height Measurement

Ocular Estimate: by using specific length of pole.

Non Instrumental methods

- **Shadow method**: a pole of convenient length is fixed upright in the ground and its height above the ground is measured. The shadows of the pole and the tree are also measured.



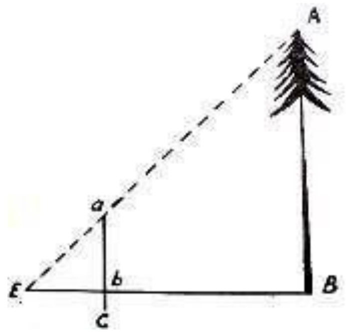
AB/ab = BD/bd, AB = BD x ab/bd

Where, AB is the tree, ab is the portion of the pole above the ground level, BD is the length of shadow of the tree and bd is the shadow of ab.

Single pole method

- Pole of about 1.5 m length vertically at arm's length in one hand in such a way that portion of the pole above the hand is equal in length to the distance o the pole from eye.

AB/ab = EB/Eb i.e. AB = EB x ab/Eb
Where,
AB = tree, ac=pole about 1.5 m long, Eb=ab



Instrumental method

- By using a instruments like hypsometer, clinometer, altimeters, abneys level, improverised calipers etc.
- All these instruments are based either on geometric principle of similar triangles or on trigonometric principles.

Principles of the height measurement

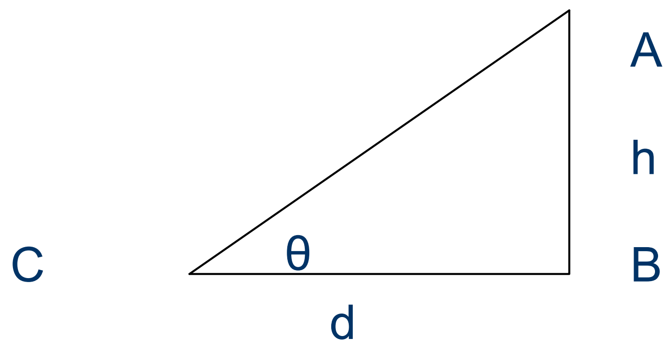
- Many types of height measuring devices and instruments in the course of time, but only a few have gained wide acceptance by practicing foresters.
- The two of the common designs are based on trigonometric principles and geometric principles.

Trigonometric principles

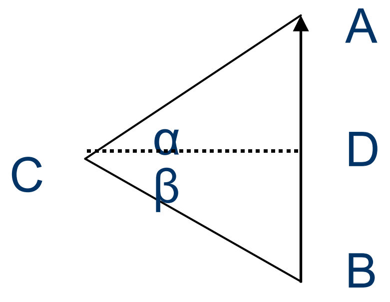
- The principles follow the basic rules of trigonometry for deriving heights of trees from distance and angle measurements. Two laws are applicable for this purpose and they are: tangent law and sine law.

Tangent law

- Applicable to right angle triangle
- Instruments based on this principle are Abney's level, clinometers, altimeter etc.
- with clinometers give the direct height reading is possible at fixed horizontal distances (15 m & 20 m) from the tree.
- For accurate results, trees must not lean more than 5° from the vertical, and the fixed horizontal distance must be determined by taped measurement.

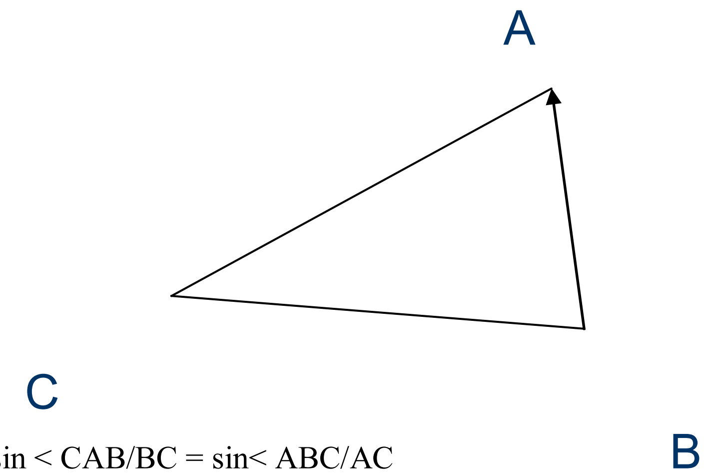


Tanθ = BC/BA, h = d x tan θ



Sine method

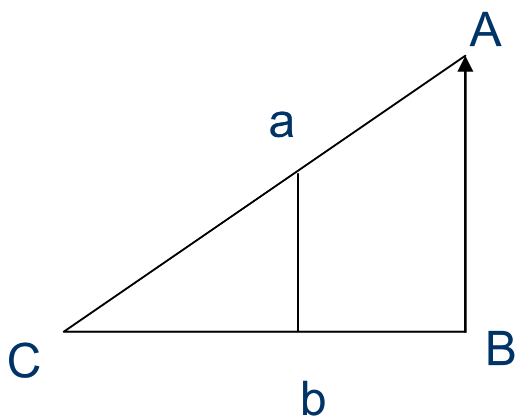
- Applicable to non right angle triangle is useful in deriving tree height in difficult conditions.
- Sines of angles are proportional to the opposite sides.



Sin<ACB/AB = sin < CAB/BC = sin< ABC/AC

Principle of similar triangle

- Corresponding angles are equal and the corresponding sides are proportional.
- By knowing the two sides of a triangle and only one side of the other, the corresponding second side of the latter can be found.
- Useful in rough estimation, not reliable for precise work.
- Eg. Christen's hypsometer, Improvised calipers



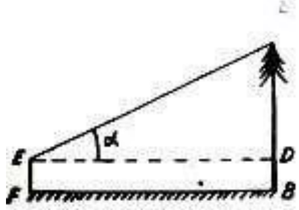
AB/ab = BC/bC,

AB = ab x BC/bC

Measurement of tree height (vertical tree) in plane and slope

On level ground

- The height of the tree is calculated with the help of the tangents of the angle to the top and the distance of the observer from the tree.

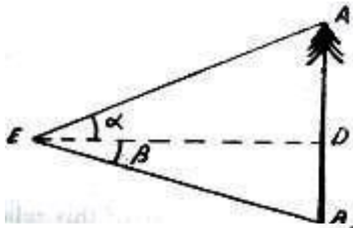


$AB = AD + BD = ED \tan\alpha + BD = BF \tan\alpha + EF$

Where, AB = tree, EF = eye height of the observer,

BF = horizontal distance **On sloping ground**

- Where the observer is standing at such a place that the top of the tree is above the eye level and the base below it.

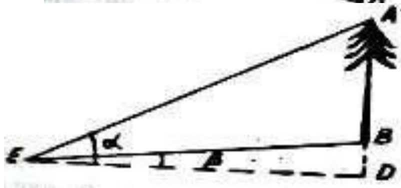


$AB = AD + DB$

$= ED \tan\alpha + ED \tan\beta = ED (\tan\alpha + \tan\beta)$

$= EB \cos\beta (\tan\alpha + \tan\beta)$

- Where top and base of the tree are above the eye level.

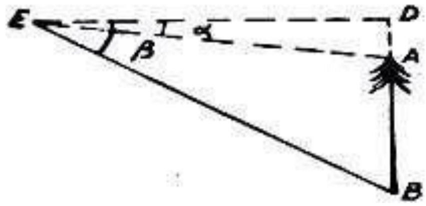


$AB = AD - BD$

$= ED \tan\alpha - ED \tan\beta = ED (\tan\alpha - \tan\beta)$

$= EB \cos\beta (\tan\alpha - \tan\beta)$

- Where base and top of the tree are below the eye level



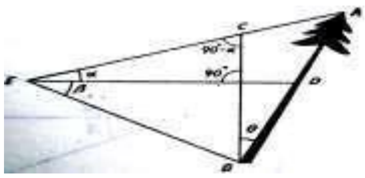
$AB = BD - AD$

$= ED \tan\beta - ED \tan\alpha = ED (\tan\alpha + \tan\beta)$

$= EB \cos\beta (\tan\alpha + \tan\beta)$

Measuring of Height of Leaning tree

- **Case – I (a):** In case of the observer standing at between the top and bottom of the tree (lean away from observer)
- $AB/\sin<AEB = EB/\sin<EAB$

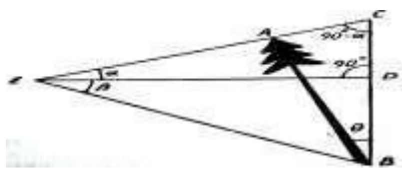


$AB = EB \sin<AEB/\sin<EAB$

$= EB \sin(\alpha+\beta)/\sin[90-(\alpha-\beta)] = EB \sin(\alpha+\beta)/\cos(\alpha-\beta)$

(b) In case of the observer standing at between the top and bottom of the tree (lean towards observer)

- $AB/\sin<AEB = EB/<EAB$



$AB = EB \sin<EAB/\sin<EAB$

$= EB \sin(\alpha+\beta)/\sin[90-(\alpha-\theta)] = EB \sin(\alpha+\beta)/\cos(\alpha-\theta)$

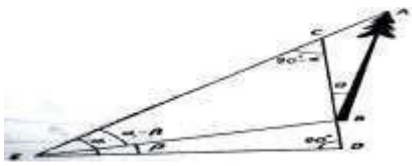
Case (II)

(a) When the observer is below the top and bottom of the tree (lean away from observer)

$AB/\sin<AEB = EB/\sin<EAB$

$AB = EB \sin<EAB/\sin<EAB$

$= EB \sin(\alpha-\beta)/\sin[90-(\alpha+\theta)] = EB \sin(\alpha-\beta)/\cos(\alpha+\theta)$



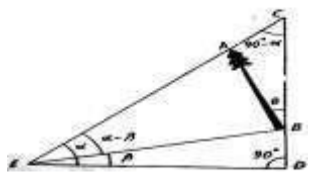
Case-II

b) This is similar to case II (a) except that the lean is towards the observer.

$AB/\sin<AEB = EB/\sin<EAB$

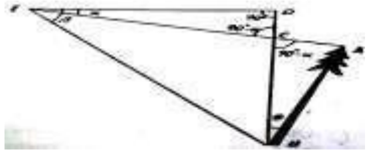
$AB = EB \sin<EAB/\sin<EAB$

$= EB \sin(\alpha-\beta)/\sin[90-(\alpha-\theta)]$



= EB sin (α-β)/cos(α-θ) ***Case (III)***

(a) When the observer is above the top and bottom of the tree (lean away from the observer).

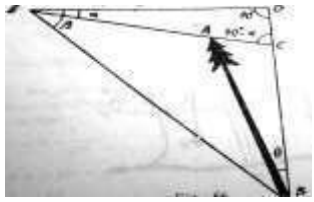


AB/sin<AEB = EB/Sin<EAB

AB = EB sin <EAB/Sin <EAB

= EB sin (β-α)/sin [90+(α-θ)] = EB sin (β-α)/cos(α-θ)

b) Same as case (III) a, but lean toward from the observer



AB/sin<AEB = EB/Sin<EAB

AB = EB sin <EAB/Sin <EAB

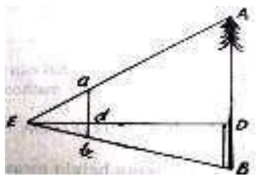
= EB sin (β-α)/sin [90+(α+θ)] = EB sin (β-α)/cos(α+θ)

Height measuring instruments

- There are various instruments to measure height of a tree.
- Height measuring instruments are called hypsometers.
- Those instruments based on trigonometrical principles are more accurate than the ones employing geometrical principles.
- The Abney's level, Haga Altimeter, Blume-Leiss Altimeter, and Sunto Clinometer are similar in accuracy.

Christen's Hypsometer

- Consists of a strip of metal, thin wood or card board about 2.5 cm wide and 33 cm length. It has two flanges or protruding edges one at the top and other at the bottom.
- Relationship: AB = BD x ab/bd where, AB = tree height, BD = staff, ab = distance between flanges, bd = distance above the inner edge of the lower flange.
- Generally used to measure the tree height up to 30 m.



Abney's level

- The instruments consists of a graduated arc mounted on a sighting tube about 6 inch long.
- The arc may have a degree, percentage or topographic scale.
- When the level bubble, which is attached to the instrument, is rotated while a sight is taken, a small mirror inside the tube makes it possible to observe when the bubble is horizontal. Then the angle between the bubble tube and the sighting tube may be read on the arc.

Sunto Clinometer

- It is a handled device housed in a corrosion-resistant aluminum body.
- A jewel bearing assembly supports the scale, and all moving parts are immerged in a damping liquid inside a sealed plastic capsule.
- It is held to one eye and raised or lowered until the hairline is seen at the point of measurement. At the same time, the position of the hairline on the scale gives the reading. Reading can be taken at 15 or 20 m distance from the tree.
- It is also available with a rangefinder and several scale combinations: percent and degrees, percent and topographic, degree and topographic and feet and metric.

Haga altimeter

- It consists of a gravity-controlled, damped, pivoted pointer and a series of scales on a rotatable, hexagonal bar in a metal, pistol shaped case.
- It includes six regular scales for use at 15, 20, 25, 30, percentage and topographic scale.
- Sight are taken through a gun type peep sight; squeezing a trigger locks the indicator needle and the observed reading is taken on the scale.
- A rangefinder is available with this instrument.

Blume-Leiss Altimeter

- It is similar in construction and operation to the Haga altimeter, although its appearance is somewhat different.
- The five regular metric scales are 15, 20, 30 and 40. A degree scale is also provided. ● All scales can be visible at the same time. ● It is available with a rangefinder.

Spiegel Relaskop

- It can be used to measure stand basal area, tree height and diameter at any point up a tree bole.
- There are several makes of the instrument and the number of bands as well as height measuring scales vary from make to make.
- It can be used as a clinometer with readings in degree or percent.
- For height measurement, the horizontal distance is first determined and then height is read directly from the corresponding height band.

Sources of errors in height measurement

- **Instrumental errors** – occur as a result of some deficiency in instrument apart from its incorrectness.
- **Personal errors** – shaking hands, misreading
- **Errors due to measurement** - due to full of shrub and undergrowth
- **Errors due to observation** – due to bushes, the base of the tree is not visible
- **Errors due to lean of trees** – the height of the tree leaning towards the observer is over estimated while that of tree leaning away from the observer is under estimated.

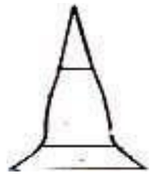
The percentage error due to lean

- $= \frac{\text{Cos (angle of elevation +/- lean angle)}}{\text{Cos (angle of elevation)}} - 1 \times 100$

Lect. 10 Measurement of Tree Form

stem form

- **Form** is the rate of taper of a log or stem
- **Taper** is the decrease in the diameter of a stem of a tree or of a log from base upwards.
- The taper varies not only with species, age, site and crop density but also in the different parts of the same tree.
- Basal portion of the tree corresponds to the frustum of **Neiloid,** the middle portion to the frustum of **Paraboloid** and the top portion to a **cone**.



Metzger's Theory

- Assumption: Tree stem should be considered as a **cantilever beam** of uniform size against the bending force of the wind.
- The wind pressure acts on the crown and is conveyed to the lower parts of the stem in an increasing measure with the increasing length of the bole.
- Thus, the biggest pressure is exerted at the base and there is a danger of tree snapping at that place, to counteract this tendency, the tree reinforces itself towards the base.
- Tapering increases if it is an isolated area, an area where largest density, in those area-tapering decreases.
- Though tapering is the natural processes which can be controlled by human interference. If competition increases, tapering decreases.

Methods of studying form

- By comparison of standard form ratios (Form factor and Form quotient)
- By classification of form on the basis of form ratios (Form class and Form point ratio), and
- By compilation of taper tables

Form Factor

- The ratio of the volume of the tree or its part to the volume of a cylinder having the same length and cross section as the tree.
- Ratio between the volume of a tree to the product of basal area and height. **F = V/Sh**

Where, F = form factor, V = tree vol, S = basal area at bh and h = ht of the tree **Types**

- Artificial form factor
- Absolute form factor
- Normal form factor
- **Artificial form factor**: known as breast height form factor. Basal area or diameter is measured at dbh and the volume refers to the whole tree both above and below the point of measurement.
- **Absolute form factor**: Basal area is taken at any convenient height and height is taken above this diameter taking. Volume refers only to that part of the above the point of measurement.
- **Normal form Factor**: Basal area or diameter is taken at constant proportion of the total height of the tree like 1/10th, 1/20th etc of the total height and volume refers to the whole tree above ground level.

Use of form factors

- To estimate volume of standing tree
- To study of law of growth

Form height (Fh)

- It is the product of the form factor and total height of tree. Fh = V/S

Form Quotient (F.Q.)

- The ratio of the mid-diameter and diameter at breast height is called form quotient. F.Q. = mid-diameter/dbh

Types

- **Normal form quotient** is defined as the ratio of mid-diameter or mid girth of a tree to its diameter or girth at breast height.
- **Absolute form quotient** is the ratio of diameter or girth of stems of one half of its height above the dbh and diameter at breast height.
- Form quotient is the third independent variable of volume table that can be used to predict the volume of a tree stem.
- **Form class:** Form class is defined as one of the intervals in which the range of form quotients of trees is divided for classification and use. Tree may be grouped into form classes expressed by form quotient intervals such as 0.5, 0.55 to 0.6 and so on.
- **Form point ratio: Form point** is defined as the point in the crown as which *wind pressure is estimated to be centered*. **Form point ratio** is defined as the relationship of the form point above ground level to the total height of the tree. If form point ratio is known, the form quotient and form class of a tree can be determined**.**

Taper tables

- It provides the actual form by diameters at fixed points from the base to the tip of a tree. Volume table can thus be prepared from taper tables in desired unit. **Types of taper table**
- **Ordinary taper tables or diameter taper tables-** give the taper directly for diameter at breast height without reference to the tree form.
- **Form class table tables-** give for different form classes the diameters at fixed points on the stem.
- Taper equations represent the expected diameter as a function of height above ground, total tree height and dbh irrespective of tree species and generalized for form class.
- Many different forms of taper equations have been developed as no single one can adequately represent all species in all situations. The use of taper equations allows us to obtain volumes for any desired portion of a tree stem by predicting upper stem diameters.

Eg. D = dbh √ (bo + b1 (h/H)+ b2 (h2/H2)

Where, d = stem diameter at any given height h above ground, H = total tree height and bo, b1 and b2 = regression coefficient

Equations for Tree

Form Hojer`s formula

d/dbh = C log c+l c

Where, d is the diameter at any point on the stem. C and c are constants for each form class, l is the distance from the top of the tree to the point at which d is measured, expressed in percentage.

Behre`s formula d/dbh = l/a+bl

Where, a and b are constants for each class, such that a +b =1 and d an l have the same meaning as given for Hojer`s formula. This formula is more consistent.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LECT- 11 Measurement of VOLUME of standing and felled tree

- The ultimate object of all mensurational activity in forest is to calculate or estimate quantity of wood contained in trees and consequently in crops not only for sale but also for research, predicting future yields, estimating increment to assess return on capital etc.
- Measurement of felled trees are to determine the quantity of merchantable volume, to obtain statistical data that could be applied to standing trees for the purpose of estimating the yield, to estimate the growing stock and to estimate the increment of woods and forests.
- Volume estimation may be made most accurately when the logs are separated and accessible to the measurer. A tree, therefore, could be separated into stem wood, which may be further divided into timber and small-wood, crown and branch wood. Stem wood may be measured after division into sections for obtaining real volume.
- The measurement requires length and mid diameter or mid girth except where the tip is measured as frustum of a cone where the diameter or girth at the ends are measured. Logs are neither cylinder nor often of any regular geometrical shape. Therefore in order to calculate the volume, the shape of a quadratic paraboloid is adopted.
- It is usual to cut the tree into logs due to irregularity in tree tapers. The lengths of the logs depend upon the rate of taper and market requirements. As the diameter at the thin end of the log determines the sawn volume that can be taken out of it, the greater the rate of taper, the lesser is the length of the log. Another consideration that affects the length of log is the mode of transport.
- When the logs are made for calculating volume of felled trees for research work, all logs including the first are of uniformly 3m in length except the top end log which may be up to 4.5m. But if the end section is more than 1.5m in length, it is left as separate rate log.
- Simple tape or a graduated rod can be used to measure the length of a given logs. Similarly, diameter tape, caliper and other optical instruments are used to measure the measure diameter and sectional area of logs.
- Logs are the round pieces of a tree with square cut ends. Normally, a log is 8 ft or over in length and suitable for lumber.
- The cross-sectional area or basal is found from the diameter as follows: Basal area $=\pi$ d2/4

Formulae for log volume calculation

- Volume has been the traditional measure of wood quantity and continues to be the most important measure in spite of increasing use of weight or biomass as a measure of forest productivity.
- Basal portion of the tree corresponds to the frustum of Neiloid, the middle portion to the frustum of Paraboloid and the top portion to a cone.
- The following table gives formula for calculation of volume of the solid of revolution together with the formula for cylinder for comparison

S.N.	Forms of solid	Volume of full solid	Volume of frustum of solid	Remarks

1	Cylinder	Sl	Sl	……
2	Paraboloid	Sl/2	S1 +S2 X l 2 Sm X l	Smalian's formula Huber's formula
3	Cone	Sl/3	S1+S2+S1S2 X l 3	
4	Neiloid	Sl/4	S1 +4Sm+S2 X l 6	Prismoidal or Newton's formula

Where, S is the sectional area at the base

S1 is the sectional area at the thick end

Sm is the sectional area at the middle

S2 is the sectional area at the thin end and

L is the length of the log or height of the solid

- Prismoidal formula or Newton's formula is the best and most accurate method for volume calculation.
- Smalian's formula over-estimates the volume. ● Huber's formula under-estimates the volume.
- Huber's formula is more easy and accurate than Smalian's formula.
- We can use Smalian's formula for calculating the volume of stacks wood.

Quarter Girth Formula

- Volume of log = (g/4)2 x L, where, g is the girth of the log at the middle (in inches) and L is the length of log (in ft).
- Volume of log in cubic feet is calculated using the following formula, V = (g/4)2 x L/144.
- This is the system of measurement used in Great Britain and also in Nepal for sale purpose when round timber is sold by volume.
- This formula gives only 78.5 % of the cubic volume of cylinders, thus allowing a loss of 21.46%.
- *Quarter Girth formula is used to estimate the standing volume of a coupe in Nepal*

Solid volume of firewood

- **Xylometric method** W: w = V: v

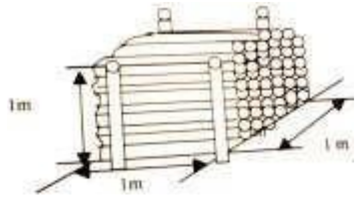
Where, W is the weight of the whole stack of wood, w is the weight of submerged pieces, V is the volume of the whole stack and v is the volume of submerged pieces.

Specific gravity method

- Specific gravity of weight of wood a piece of wood = wt. of same volume of water or = density of wood/density of water

Measurement of Staked volume / measurement of volume of felled tree:

- It is the bulk volume occupied by pieces of wood one meter long piled on one meter width, and one meter high.
- This volume contains air space and wood in variable proportions a/c to the form of the logs.
- Piling co-efficient has to be used to get the actual volume.
- Piling co-efficient = π/4=0.7854, if all pieces of wood were cylindrical and of the same diameter.



Dimensions of Chatta

- Standard size of Chatta = 5 ft x 5 ft x 20 ft = 500 cft including air space.
- One Chatta in metric unit = 14.16 m3

  The following formula should be used in order to calculate the amount of fuelwood that is obtained from the total volume up to 10 cm top-diameter of class III and the remaining portions up to 10 cm top-diameter of class I and II trees which could not be used as timber.

- Amount of fuelwood in terms of number of Chatta

= (0.8778xvol.I+1.4316xvol.II+3xvol.III)/1000

Where, Vol.I = gross volume of up to 20 cm top-diameter of class I trees, Vol.II = gross volume of up to 20 cm diameter of class II trees and Vol.III = gross volume of up to 10 cm top-diameter of class III trees.

(all trees except Khayar having dbh of 27.94 cm (11 in) or more should be classified) Class I = Green, dead or dying, standing or uprooted tree having good and solid trunk in which sign of any disease or wound is not visible from outside.

Class II = Green, dead or dying, standing or uprooted tree in which complete volume could not be realised due to hollowness or other sigh of defect but at least two straight logs of each 1.84 m (6ft) long or one straight log of 30.5m (10 ft) long which should have at least 20 cm diameter could be recovered.

Class III = Remaining trees which do not belong to class I and class II

Measurement of volume of felled and standing trees, age determination of trees.

Tree volume is one of many parameters that are measured to document the size of individual trees. **Tree volume measurements** serve a variety of purposes, some economic, some scientific, and some for sporting competitions. Measurements may include just the volume of the trunk, or the volume of the trunk and the branches depending on the detail needed and the sophistication of the measurement methodology.

Other commonly used parameters, outlined in Tree measurement: Tree height measurement, Tree girth measurement, and Tree crown measurement.

Volume measurements can be achieved via tree climbers making direct measurements or through remote methods. In each method, the tree is subdivided into smaller sections, the dimensions of each section are measured and the corresponding volume calculated. The section volumes are then totaled to determine the overall volume of the tree or part of the tree being modeled. In general most sections are treated as frustums of a cone, paraboloid, or neiloid, where the diameter at each end and the length of each section is determined to calculate volume. Direct measurements are obtained by a tree climber who uses a tape to measure the girth at each end of a segment along with its length. Ground-based methods use optical and electronic surveying equipment to remotely measure the end diameters and the length of each section.

The largest trees in the world by volume are all Giant Sequoias in King"s Canyon National Park. They have been previously reported by trunk volume as: General Sherman at 52,508 cubic feet (1,486.9 m^3); General Grant at 46,608 cubic feet (1,319.8 m^3); and President at 45,148 cubic feet (1,278.4 m^3). The largest non-giant Sequoia tree currently standing, Lost Monarch, is, at 42,500 cubic feet (1,203.5 m^3), larger than all but the top five largest living giant sequoias. The Lost Monarch is a Coast Redwood (Sequoia empervirens) tree in Northern California that is 26 feet (7.9 m) in diameter at breast height (with multiple stems included), and 320 feet (98 m) in height. In 2012 a team of researchers led by Stephen Sillett did a detailed mapping of the branches of the President tree and calculated the volume of the branches to be 9,000 cubic feet (250 m^3). This would raise the total volume for the President from 45,000 cubic feet to 54,000 cubic feet (1,500m^3) surpassing the volume of the General Grant Tree. The branch volume of the General Grant and General Sherman Trees have yet to be measured in this detail.

Standing tree volume

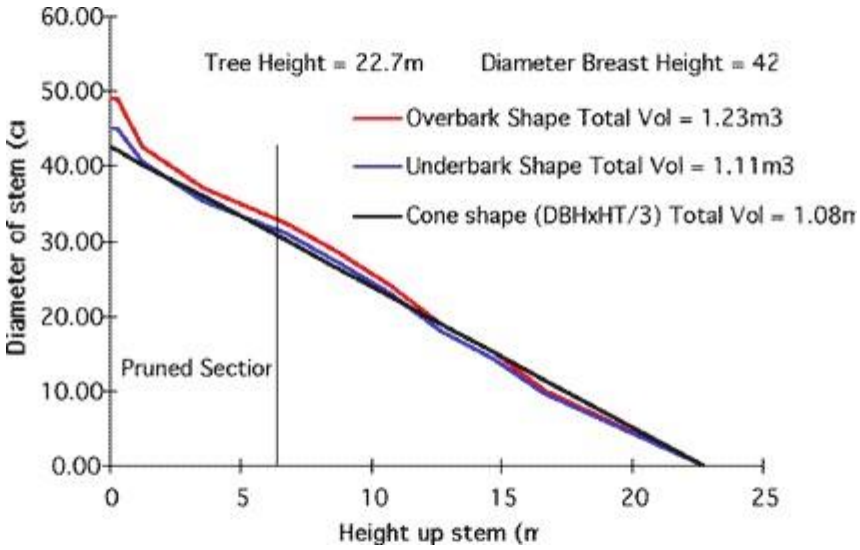
Using measures of Diameter at Breast Height (DBH) and Total Tree Height (Ht), an estimation of total tree volume can be made by assuming the tree has a particular form. For example, if we assume the tree is conical in shape, with the DBH equivalent to the diameter at the base of the cone, then the following formula is appropriate:

Tree volume (m3) = Tree Basal Area (m2) x Tree Height (m) / 3 =
(DBH/200)2 x 3.142 x Ht / 3

So, if a tree was 22.7m tall and 42.6cm in DBH, the total tree volume would be:

Tree volume (m3) = (42.6/200)2 x 3.142 x 22.7 / 3 = 1.08 m3

As the diameter is actually measured at 1.3 metres above the ground, not at the base, most trees carry a bit more volume than the cone-form would suggest. This formula is a conservative estimate of total underbark tree volume.



Measurements of a 10 year old eucalypt pruned to 6.5m. Assuming the tree has a conical shape this can be a useful estimate of underbark volume. Source Reid and Stephen (2001) Farmers Forest.

More detailed formulae are available for particular species grown in some areas, although rarely for farm grown trees other than pine.

It is important to be consistent in choice of method of measuring volume, particularly when comparing growth on different sites or over time.

If a tree is clearly not conical or if a farmer is only interested in the volume of the butt log it may be more appropriate to measure the volume of the lower log only.

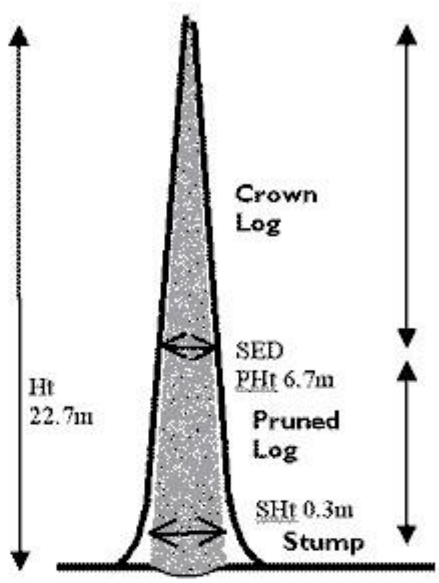
Estimating the volume of the parts of a standing tree

Assuming a tree is perfectly conical makes it easy to estimate the volume of different sections of the trunk. All that is required is an estimate of the tree taper or rate at which the diameter decreases with height

Taper (T) of a conical tree = Diameter (DBH)/[Height(Ht) – 1.3] cm/m

For example: For a conical tree of 42.6cm DBH and 22.7m tall, the taper (T) is 1.9cm/m.

Using the taper equation, it is possible to estimate the diameter at different points up the tree. For example if the same tree was pruned to 6.7 metres and the stump height was 30cm then it may be assumed to have the following dimensions:



- Total Tree Height (Ht) = 22.7m

- Diameter Breast Height (DBH) = 42.6cm

- Pruned Height (PHt) = 6.7m

- Stump Height (SHt) = 0.3m

- Estimated total tree Volume (Vol)

Vol = (DBH/200)2 x (x Ht / 3 = 1.08m3

- Estimated Taper (T)

T = DBH/Ht = 1.9cm/m

- Underbark diameter at stump height (LED)

LED = DBH – SHt x T = 42.03cm

- Underbark diameter at pruned height (SED)

SED = DBH – PHt x T = 29.9cm

- Crown Log Vol (Cvol)

Cvol = (SED/200)2 x (x (Ht-PHt) / 3 = 0.37m3

- Stump Vol (Svol)

Svol = Vol - (LED/200)2 x (x (Ht-SHt) / 3 = 0.04m3 - Pruned Vol (Pvol)

Pvol = Vol – Cvol – Svol = 1.08-0.37-0.04 = 0.67m3

It is interesting to note that in well-spaced, pruned trees the taper of the pruned butt log tends to decline over time resulting in a more cylindrical log at the base and a more highly tapered upper crown. The graph above shows some evidence of greater diameter growth in the section just above the pruned log, even in a ten-year-old pruned tree.

Volume Calculations

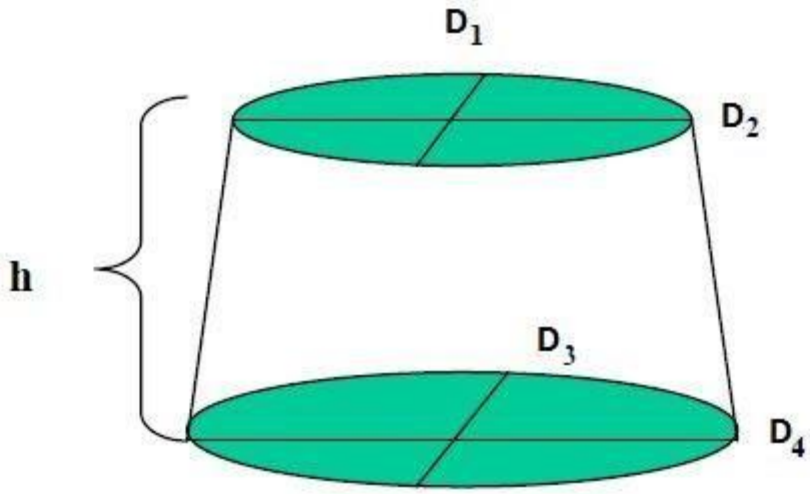
To calculate trunk volume, the tree is subdivided into a series of segments with the successive diameters being the bottom and top of each segment and segment length being equal to the difference in height between the lower and upper diameters, or if the trunk is not vertical, the segment length can be calculated using the limb length formula above. Whether using the aerial or ground based methods, the diameter or girth measurements do not need to be evenly spaced along the trunk of the tree, but a sufficient number of measurements need to be taken to adequately represent the changes in diameter of the trunk. Cumulative trunk volume is calculated by adding the volume of the measured segments of the tree together. Where segments are short, the volume of each segment is calculated as the volume of a frustum of a cone where volume is calculated by any of the three forms:

Volume= $h(\pi/3)(r_1^2 + r_2^2 + r_1 r_2)$

Volume= $h(\pi/12)(D_1^2 + D_2^2 + D_1 D_2)$

Volume= $h/3(A_1 + A_2 + (A_1 A_2)^{1/2})$

A similar, but more complex formula can be used where the trunk is significantly more elliptical in shape where the lengths of the major and minor axis of the ellipse are measured at the top and bottom of each segment.[1][2]

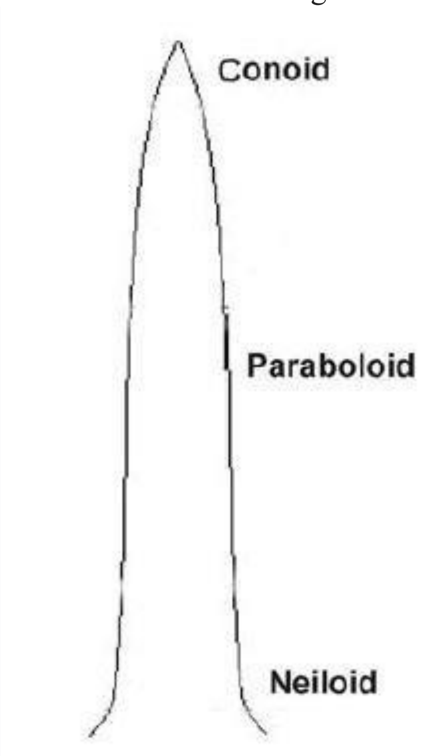


Let D_1 = major axis of upper ellipse of the frustum D_2 = minor axis of upper ellipse of the frustum D_3 = major axis of lower ellipse of the frustum D_4 = minor axis of lower ellipse of the frustum h = height of frustum V = volume of frustum $\pi = 3.141593$

Volume= $h(\pi/12)\{[(D_1)(D_2)] + [(D_3)(D_4)] + [(D_1 D_2 D_3 D_4)^{1/2}]\}$

While this formula is more involved than the equivalent for a circle, if the major and minor axis of each ellipse are equal, the result is the more familiar formula for the frustum of a right circular cone.

The volume calculations for these individual frustums of trunk segments can be further refined by considering the overall shape of the trunk. Tree trunks change shape, or more appropriately, curvature multiple times from base to top. It is not uncommon to see the base of a tree as neiloid in shape for 3 to 10 feet. This neiloid shape then changes to a cylinder or paraboloid for perhaps several tens of feet and then to a cone for the remaining distance.



Tree shape with height

The best method for modeling that is to divide the trunk into adjacent segments no more than 3 to 5 feet in height/length and then apply either the cone, paraboloid, or neiloid frustum form to each.[23][24] This is a labor-intensive process. To gain efficiency, longer sections can be chosen that appear to the eye to have uniform curvature. However, the longer the segment, the more important it is to choose the optimum solid. Over longer frustums, the greater volume contribution of the paraboloid or the lesser volume of the neiloid becomes apparent when compared to the basic conical form. Therefore, when modeling longer frustums the measurer needs to perform independent checks to insure that the right solid has been chosen. One way to check is to take a diameter measurement at an intermediate point and then project what the diameter would be for the chosen model at the point. If the projected diameter is substantially greater or lesser than the measured diameter, then the selected solid is not the right choice. In this case, an intermediate form that combines the two forms through weighting may be appropriate. The measurer selects weights and applies them to each solid formula to arrive at an intermediate result. Each frustum can represent a different parent cone, paraboloid, or neiloid so that there is not a need to impose a single form on the entire tree.

The formula for the volume of a frustum of a paraboloid is: $V = (\pi h/2)(r_1^2 + r_2^2)$, where h = height of the frustum, r_1 is the radius of the base of the frustum, and r_2 is the radius of the top of the frustum. This allows us to use a paraboloid frustum where that form appears more appropriate than a cone. Frustums are then dictated by visual inspection.

As an extension of this approach, the neiloid form is one whose sides are concave, so its volume is less than that of a cone. The neiloid form often applies near the base of tree trunks exhibiting root flare, and just below limb bulges. The formula for the volume of a frustum of a neiloid: $V = (h/4)[A_b + (A_b^2 A_u)^{1/3} + (A_b A_u^2)^{1/3} + A_u]$, where A_b is the area of the base and A_u is the area of the top of the frustum. This volume may also be expressed in terms of radii:

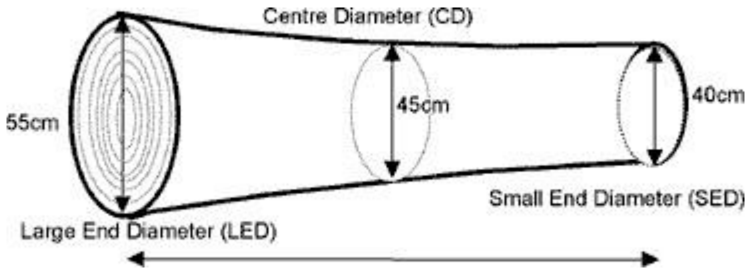
$$V = \left(\frac{h}{4}\pi\right)\left(r_b^2 + r_b^{\frac{4}{3}} r_u^{\frac{2}{3}} + r_b^{\frac{2}{3}} r_u^{\frac{4}{3}} + r_u^2\right)$$

The final tree volume is the sum of the volumes for the individual frustum sections for the trunk, the volumes of sections measured as bifurcations, the volume of the basal flare, the volume of miscellaneous unusual sections, and the volumes of the limbs (if applicable.)

Estimating the volume of a log on the ground/ volume of felled trees:

If a tree has been felled and the bark removed it is relatively easy to measure log volume. However, there are a number of different equations that may be used. Farmers need to agree with sawmillers on one method before selling logs to the mill. Log buyers may dictate that log volumes be determined from centre diameters, small end diameters, an average of the diameters at each end or from the average cross sectional area at each end. Where the latter method may be more accurate, the others are much quicker and may better reflect log value.

The table below shows a number of commonly used methods. Whilst Method 4 (the Smalian method) is generally considered the most accurate, Method 3 (the Huber method), based on the centre diameter, is more commonly used. Some millers may prefer Method 1. If the bark is still on the log, it must be accounted for when determining the diameters. This can be done by judging bark thickness using a knife or debarking the log at that point.



Method	Technique	Calculation	Result
1	Based on small end diameter	Vol (m^3) = $(40/200)^2$ x 3.142 x 6	= 0.75 m^3
2	Based on average end diameter	Vol (m^3) = $(47.5/200)^2$ x 3.142 x 6	= 1.06 m^3
3	Huber: Based on centre diameter	Vol (m^3) = $(45/200)^2$ x 3.142 x 6	= 0.95 m^3
4	Smalian: Based on average end area	Vol (m^3) = $\frac{(55/200)^2+(40/200)^2}{2}$ x 3.142 x 6	= 1.09 m^3

Determining Tree Age

An approximate age for many young conifers can be determined by “counting the whorls.” Some trees, including most conifers growing in the Pacific Northwest, have *determinate* height growth. This means that they put on one “flush of growth” each year, and that this year‟s growth is determined by last year‟s bud. The terminal and lateral buds at the tips of the tree break bud, or “flush” in the spring (Figure 4.2). The stems or “leaders” produced by these buds elongate until some time in July, and then set new buds for the following spring.

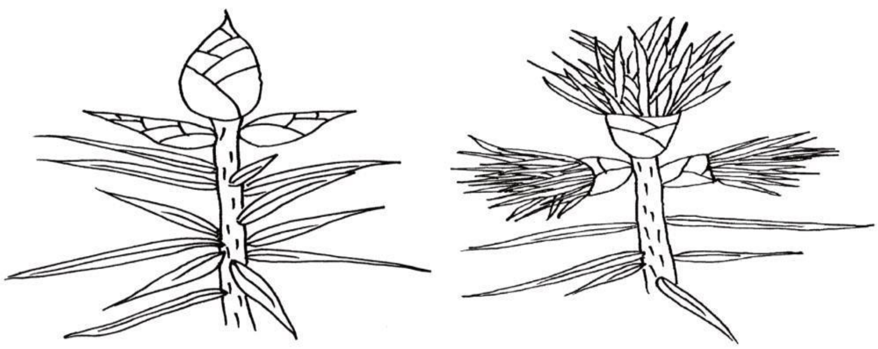


Figure 4.2. Terminal buds at the tip of the stem (left) flush and grow new branches and leaves each year (right). The center becomes the new leader, or main stem. The lateral or side buds become new lateral branches.

A tree increases in height by the length of the new leader growth produced by the terminal bud (from old bud to new bud). In addition, the lateral buds flush and produce a new whorl of branches at the base of the leader (old bud location) (Figure 4.3). This process is repeated every year. Therefore, each whorl of branches and the stem growth immediately above it (up to the next whorl) represent one year of growth.

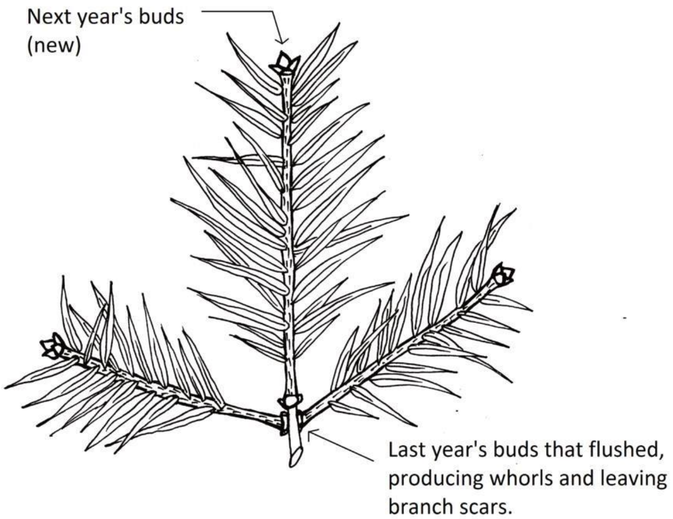


Figure 4.3. An annual flush of growth represents one year, or one whorl of growth.

Field Technique Tips for Counting Whorls:

Because each whorl represents one year of growth, one can estimate age on young trees with determinate height growth by counting the whorls.

1. On most trees, the lowest tree branches are systematically dropped as the tree grows and the sun no longer hits the base of the tree. Therefore, when estimating age using this method, it is important to include the bottom-most stubs and/or knots where it is evident branches once existed.
2. Two to four years should be added to most species to allow for the time between seedling germination and evidence of branch whorls on the trunk (Figure 4.4).
3. Small single branches between major branch whorls do not constitute a true whorl or year of growth. Do not count these false whorls.
4. A very short increase in length between whorls that seems unlike the other years‟ growth may indicate a "lammas" year, in which the tree flushed twice, often in response to extraordinary growing conditions. Ignore those years unless it is evident that some injury is responsible for the very short internode (Figure 4.4).

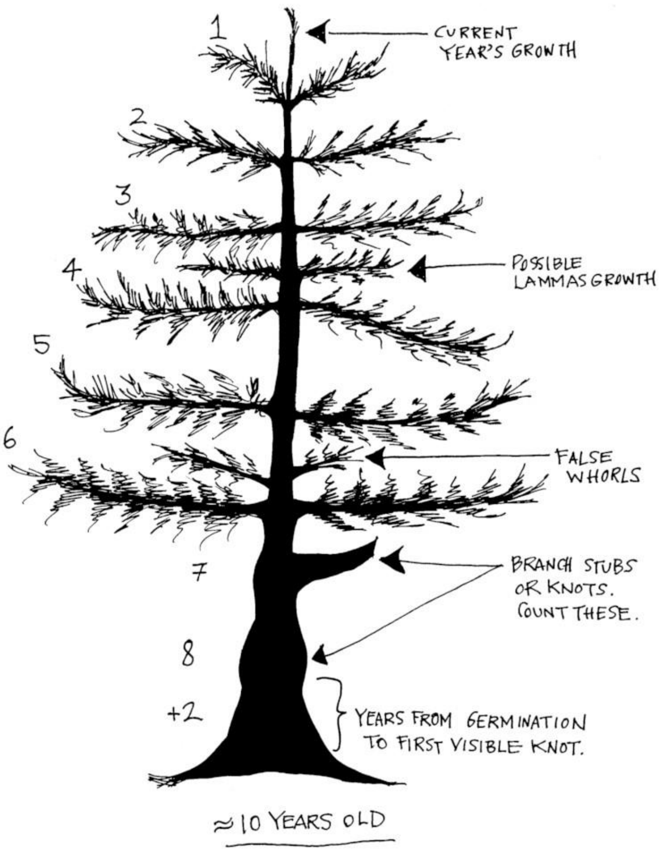


Figure 4.4. Counting the whorls to determine age of a young conifer. Lammas growth and false whorls are ignored. Lower stem is examined for knots, and time to first visible knot is estimated and added in — generally 2-4 years.

This method of "counting the whorls" usually works very well up Forest Measurements: an Applied Approach to fifteen years of age or so for conifers such as Douglas-fir, spruces (*Picea* spp.), pines (*Pinus* spp.) and true firs (*Abies* spp.). It is more challenging for cedars (*Thuja* spp., *Chamaecyparis* spp.), hemlocks (*Tsuga* spp.), and some hardwoods. One really has to get close to the tree, look carefully for evidence of bud scars, and know the growth habits of the species.

Forest Setting

Larger trees growing in a forest present the greatest challenge. As noted above, it is very difficult to estimate tree age simply from size. So much depends on the tree‟s microenvironment (access to light, water, space and nutrients), its unique species-dependent growth habits, and the events that alter the tree‟s environment or health over the course of its life. The frequency and intensity of disturbances such as fire, insect attacks, or windstorms profoundly influence tree growth over time.

Trees growing in managed forests, particularly evenaged "second growth" or "third growth" forests, were likely planted. Foresters record the year of planting and seedling age at time of planting. Most companies will have year of establishment printed on company forest maps or indicated on company aerial photos for ease of use. In these cases, simply researching office records before one goes out to the field will provide stand age. Trees growing in naturally regenerated stands, unmanaged stands, or stands managed for an unevenaged structure are harder to evaluate. In these cases, individual tree age can vary greatly from tree to tree. Knowledge of tree silvics can help with ballpark estimates. For example, a young (< 30 yrs.)true fir will have smooth bark with resin blisters. This gradually develops into plates or fissures as the tree ages. A tree over 100 years will have regular, geometric shapes in the bark patterns. The crown of a very old tree will also have a rounded top, different than the tiered leader of a young tree. On Douglas-fir, the smooth bark gives way to thick fissures in the bark. But these type of physical characteristics, without some site history clues, may only get a person to within about 30 years of the actual age.

ANNUAL RING COUNTS

The most direct way of determining tree age is to count the annual rings on a tree‟s stump or a round “cookie” cut from the tree. In the Pacific Northwest, trees produce one “ring” of diameter growth each year, so the number of rings present on a cross-section of the tree‟s trunk represents the tree‟s age at that height. Counting rings on a stump will result in a pretty accurate estimate of the former tree‟s age. Counting rings from a cookie cut at a height of ten feet or twenty feet will tell you how many years the tree grew after it reached that particular height (Figure 4.5). In fact, researchers examine cookies cut from regular intervals along fallen trees to derive information about species‟ growth rates, and sometimes to investigate evidence of historical events such as fires, droughts, insect outbreaks, etc. in a science called **dendrochronology**.

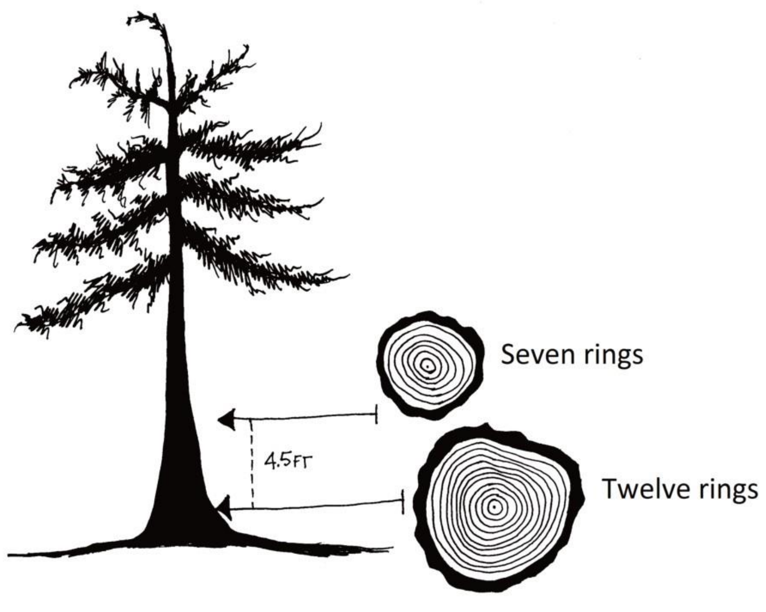


Figure 4.5. A round “cookie” cut at the base of the tree reveals 12 years of growth; at dbh, seven rings are counted, indicating it took five years to grow from stump to dbh.

Increment Boring

Since counting a tree‟s annual rings is a reliable way to estimate its age when records are unavailable, this method has been adapted for living trees. An instrument called an **increment borer** extracts a small, pencil-sized piece of wood, or core sample, from the trunk of the tree. A mini-auger is drilled by hand from the bark to the center (pith) of the tree, and the resulting core sample extracted from the hole displays the annual rings (or increments of growth) of the tree at that point in the tree (Figure 4.6). The tree then "pitches" the hole over, filling the small cavity with resin.

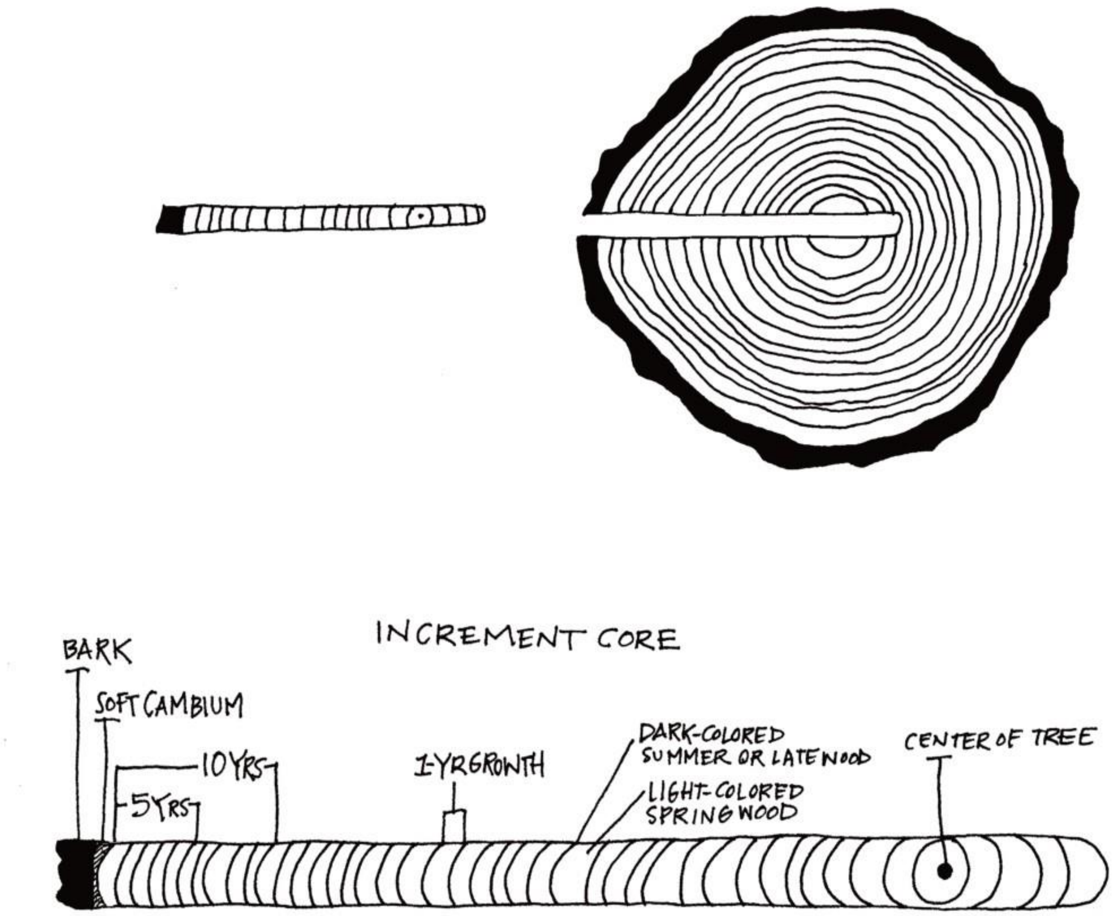


Figure 4.6. A cross-section of a tree that has been bored, showing the displaced core sample.

The standard location for taking increment core samples from a tree is diameter at breast height (DBH). There are a number of reasons for doing so.

- It is a comfortable height for most people to turn the handle of the increment borer, and to extract the core sample. (Imagine lying on your stomach to try to obtain a core sample from a one-foot stump!)
- There is ample room for the borer handle to turn. (At the base of the tree, one would constantly hit the ground or roots of the tree.)
- Brush and other vegetation do not have to be cut away in order to operate the borer.
- There is generally room to avoid oddities in the tree‟s trunk – branch whorls, cankers, etc.

- Age/diameter relationships can be developed.

Because increment core samples are obtained at dbh, it is important to note on a data sheet that the age estimate is "DBH Age." If one is using tree age to track growth on a chart or determine site index, it is also important to note whether or not the *chart* uses dbh age or total tree age. If total tree age is required, then the technician must estimate how many years it took the tree to grow to dbh (4.5 feet). This number (usually 4-8 years) is added to the core sample age to estimate total tree age.

INSTRUMENTS FOR INCREMENT BORING

Increment borers are tidy instruments that consist of a handle (that serves double duty as a case), a bit and an extractor. (Figure 4.7). The bit is locked onto the handle, making a "T"shaped instrument, then twisted into the tree. Once the bit has reached a little more than halfway through the trunk"s diameter, the extractor, a thin metal sleeve, is pushed in, then pulled out as described under *Field Techniques for Increment Boring.*

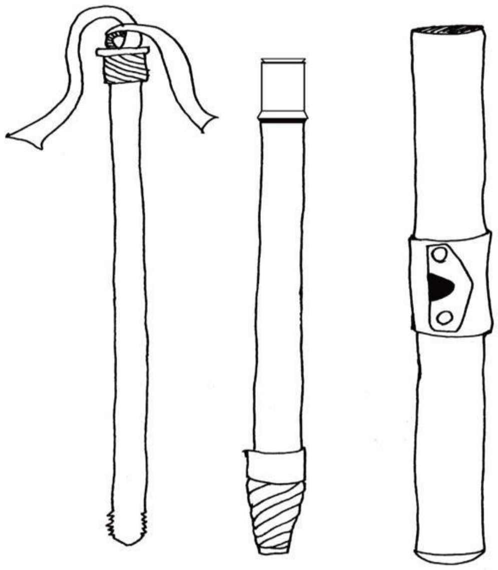


Figure 4.7. Borer extractor (left), bit (center) and handle (right). The square end of the bit is inserted into the center of the handle where the clasp is located.

Caution:

Ring counts are not foolproof! For example, many tropical trees and diffuse-porous hardwoods have growth rings that are nearly indistinguishable. Trees may also produce "false rings" during years of unusual weather conditions (e.g. drought followed by high rain, lammas years), or indistinct (missing) rings in years of extreme drought or defoliation. The older the tree, the more opportunities there are for abnormalities. Therefore, it is important to rememberthat we can only obtain *estimates* of tree age.

12 & 13 Agroforestry – definitions, importance, Classification of Agroforestry systems, criteria of selection of trees in agroforestry

Agroforestry is a collective name for land-use systems involving trees combined with crops and/or animals on the same unit of land. It combines

i) production of multiple outputs with protection of resource base; ii) places emphasis on the use of multiple indigenous trees and shrubs; iii) particularly suitable for low-input conditions and fragile environments ; iv) It involves the interplay of socio-cultural values more than in most other land-use systems;

v) It is structurally and functionally more complex than monoculture.

Definition

Agroforestry is any sustainable land-use system that maintains or increases total yields by combining food crops (annuals) with tree crops (perennials) and/or livestock on the same unit of land, either alternately or at the same time, using management practices that suit the social and cultural characteristics of the local people and the economic and ecological conditions of the area. or

Agroforestry is a collective name for a land-use system and technology whereby woody perennials are deliberately used on the same land management unit as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. In an agroforestry system there are both ecological and economical interactions between the various components.

Importance of agroforestry:

A) Environmental

i) Reduction of pressure on natural forests.

ii More efficient recycling of nutrients by deep rooted trees on the site

iii) Better protection of ecological systems

iv) Reduction of surface run-off, nutrient leaching and soil erosion through impeding effect of tree roots and stems on these processes

v) Improvement of microclimate, such as lowering of soil surface temperature and reduction of evaporation of soil moisture through a combination of mulching and shading

vi) Increment in soil nutrients through addition and decomposition of litterfall.

vii) Improvement of soil structure through the constant addition of organic matter from decomposed litter.

B) Economic

i) Increment in an outputs of food, fuel wood , fodder, fertiliser and timber;

ii) Reduction in incidence of total crop failure, which is common to single cropping or monoculture systems

iii) Increase in levels of farm income due to improved and sustained productivity

C) Social

i) Improvement in rural living standards from sustained employment and higher income

ii) Improvement in nutrition and health due to increased quality and diversity of food outputs

iii) Stabilization and improvement of communities through elimination of the need to shift sites of farm activities.

Classification of Agroforestry systems

Nair (1987) has classified the agroforestry systems based on the following four criteria.

A. Structural Basis
B. Functional basis
C. Socio economic Basis
D. Ecological basis

A. STRUCTURAL BASIS
a) Nature of Components
b) Arrangements of Components

a) **Nature of Components**

1. Agricultural systems
2. Silvopastoral systems
3. Agrosilvopastoral systems
4. Other systems

1. Agricultural systems

i. Improved fallow species in shifting cultivation
ii. The taungia system
iii. Multispecies tree gardens
iv. Alley cropping
v. Multipurpose trees and shrubs on farmlands
vi. Crop combinations with plantation crops
vii. Agroforestry fuel wood plantations
viii. Shelter belt s ix. Wind breaks
x. Soil conservation hedges

2. Silvopastoral systems

i) Protein bank
ii) Live fence of fodder trees and hedges
iii) Trees and shrubs on pastures

3. Agrosivopastoral systems

i)Home gardens
ii) woody perennials for browse, mulch, green manure, soil conservation

4. Other systems

i) Apiculture with trees
ii) Aquaforestry
iii) Multipurpose wood lots

b) Arrangement of components

1. Spatial arrangement
2. Temporal arrangement

B. FUNCTIONAL BASIS

i) Productive functions
ii) Protective functions

i) Productive functions

Food
Fodder
Fuel wood
Cloths
Shelter
NTFPs
Protective functions
Wind breaks
Shelterbelts
Soil conservation
Soil improvement
Shade

C. SOCIO ECONOMIC CLASSIFICATION

i) Commercial systems
ii) Intermediate systems
iii) Subsistence systems

D. ECOLOGICAL CLASSIFICATION

i) Humid / sub humid
ii. Semiarid / arid
iii. Highlands

1. STRUCTURAL BASIS :
A. NATURE OF COMPONENTS

I) AGRISILVICULTURAL SYSTEMS


In this system, agricultural crops are intercropped with tree crops in the interspace between the trees. Under this system agricultural crops can be grown upto two years under protective irrigated condition and under rainfed farming upto four years. The crops can be grown profitably upto the above said period beyond which it is uneconomical to grow grain crops. However fodder crops, shade loving crops and shallow rooted crops can be grown economically. Wider spacing is adopted without sacrificing tree population for easy cultural operation and to get more sunlight to the intercrop. Performance of the tree crops is better in this system when compared to monoculture.

II) SILVOPASTORAL SYSTEMS

The production of woody plants combined with pasture is referred to Silvipasture system. The trees and shrubs may be used primarily to produce fodder for livestock or they may be grown for timber, fuelwood, fruit or to improve the soil. **This system is classified in to three categories**

a) Protein bank
b) Livefence of fodder trees and hedges
c) Trees and shrubs on pasture


a) Protein bank:

In this Silvipastoral system, various multipurpose trees (protein rich trees) are planted in or around farmlands and range lands for cut and carry fodder production to meet the feed requirement of livestock during the fodder deficit period in winter.
Example: *Acacia nilotica, Albizia lebbeck, Azadirachta indica, Leucaena leucocephala, Gliricidia sepium, Sesbania grandiflora*

b) Livefence of fodder trees and hedges:
In this system, various fodder trees and hedges are planted as live fence to protect the property from stray animals or other biotic influences.
Example: *Gliricidia sepium, Sesbania grandiflora, Erythrina sp, Acacia sp.*

c) Trees and shrubs on pasture:
In this system, various tree and shrub species are scattered irregularly or arranged according to some systemic pattern to supplement forage production.
Example: *Acacia nilotica, Acacia leucophloea ,Tamarindus indica, Azadirachta indica.*

III) AGROSILVOPASTORAL SYSTEMS

The production of woody perennials combined with annuals and pastures is referred Agrisilvopastural system.
This system is grouped into two categories.

a) Home gardens
b) Woody hedgerows for browse, mulch, green manure and soil conservation

a) Home gardens

This system is found extensively in high rainfall areas in tropical South and South east Asia. This practice finds expression in the states of Kerala and Tamil Nadu with humid tropical climates where coconut is the main crop. Many species of trees, bushes , vegetables and other herbaceous plants are grown in dense and in random or spatial and temporal arrangements. Most home gardens also support a variety of animals. Fodder grass and legumes are also grown to meet the fodder requirement of cattle. In India, every homestead has around 0.20 to 0.50 ha land for personal production.

Home gardens represent land use systems involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and livestock within the compounds of individual houses. The whole tree- crop- animal units are being intensively managed by family labour. Home gardens can also be called as **Multitier system** or **Multitier cropping.**

Home gardens are highly productive, sustainable and very practicable. Food production is primary function of most home gardens.

Structure of Home Gardens:

Home gardens are characterized by high species diversity and usually 3-4 vertical canopy strata. The layered configuration and compatible species admixture are the most conspicuous characteristics of all home gardens. Generally all home gardens consist of an herbaceous layer near the ground, a tree layer at the upper levels and an intermediate layer. The lower layer can be partitioned into two, the lowermost being at less than 1.0m in height, dominated by different vegetables and the second layer of 1.0 -3.0/m height comprising food crops such as banana, papaya and so on. The upper tree layer can also be divided into two, consisting of emergent , full grown timber and fruit trees occupying the upper most layer of 25m height and medium size trees of 10-20m occupying the next lower layer. The intermediate layer of 5-10m height is dominated by various fruit trees.

Choice of species:

a) Woody species: Anacardium occidentale,Artocarpus heterophyllus, Citrus spp, Psiduim guajava, Mangifera indica, Azadirachta indica, Cocus nucifera,

b) Herbaceous species: Bhendi, Onion, cabbage, Pumpkin, Sweet potato, Banana, Beans, etc.

b) Woody Hedgerows:

In this system various woody hedges, especially fast growing and coppicing fodder shrubs and trees are planted for the purpose of browse, mulch, green manure, soil conservation etc. The following species viz., *Erythrina sp, Leucaena luecocephala, Sesbania grandiflora* are generally used.

IV) OTHER SYSTEMS

a) Apiculture with trees: In this system various honey (nector) producing trees frequently visited by honeybees are planted on the boundary of the agricultural fields

b) Aquaforestry: In this system various trees and shrubs preferred by fish are planted on the boundary and around fish ponds. Tree leaves are used as feed for fish. The main role of this system is fish production and bund stabilization around fish ponds

c) Mixed wood lots: In this system, special location specific MultiPurpose Trees (MPTs) are grown mixed or separately planted for various purposes such as wood, fodder, soil conservation , soil reclamation etc.

B. ARRANGEMENT OF COMPONENTS

I) Spatial arrangement

II) Temporal arrangement

) Spatial Arrangement: Spatial arrangement of plants in an agroforestry mixture may result in dense mixed stands (as in home gardens) or in sparse mixed stands (as in most systems of trees in pastures).

b) 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 silvipastoral systems may involve grass leys in rotation with some species of grass remaining on the land for several years. These temporal arrangement of components in agroforestry are termed coincident, concomitant, overlapping, separate and interpolated.

2. FUNCTIONAL BASIS

All agroforestry systems have two functions.

A) Productive functions,

B) Protective functions

A) Productive functions

The Productive functions are:

I) Food

II) Fodder

III) Fuel wood

IV) Cloths

V) Shelter

VI) NTFPs

B) Protective functions

The Protective functions are:

i) Wind breaks
II) Shelterbelts
III) Soil conservation
IV) Soil improvement

3. SOCIO-ECONOMIC CLASSIFICATION

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

A) Commercial Agroforestry systems
B) Intermediate Agroforestry systems
C) Subsistence Agroforestry systems

A) Commercial AF systems:

The term commercial is used whenever the scale of the production of the output is the major aim of the system.

Examples:

a) Commercial production of plantation crops such as rubber, oilpalm, and coconut with permanent underplanting of food crops, pastures

b) Commercial production shade tolerating plantation crops such as coffee, tea and cocoa under overstorey of shade trees

B) Intermediate AF systems:

Intermediate systems are those between commercial and subsistence scale of production and management.

Examples:

Production of perennial cash crops and subsistence food crops undertaken on farms wherein the cash crops fulfill the cash needs and the food crops meet the family,,s food needs.

C) Subsistence AF systems:

Subsistence AF systems are those wherein the use of land is directed towards satisfying basic needs and is managed mostly by the owner and his family.

4.ECOLOGICAL CLASSIFICATION

A) Humid / sub humid

B) Semiarid / arid
C) Highlands

A) Agroforestry systems in Humid / Subhumid lowlandsExamples:
Homegardens, Trees on rangelands and pastures, improved fallow in shifting cultivation and Multipurpose woodlots.
B) Agroforestry systems in Semiarid and arid lands Examples:
Various forms of silvopastoral systems, wind breaks and shelterbelts. **C)**
Agroforestry systems in Tropical High lands Examples:
Production systems involving plantation crops such as coffee, tea, use of woody perennials in soil conservation and improved fallow.

Criteria of selection of trees in agroforestry

In agroforestry, particular attention is placed on multiple purpose trees or perennial shrubs. The most important of these trees are the legumes because of their ability to fix nitrogen and thus make it available to other plants.

The roles of trees on the small farm may include the following:

- Sources of fruits, nuts, edible leaves, and other food.
- Sources of construction material, posts, lumber, branches for use as wattle (a fabrication of poles interwoven with slender branches etc.) and thatching.
- Sources of non-edible materials including sap, resins, tannins, insecticides, and medicinal compounds.
- Sources of fuel.
- Beautification.
- Shade.
- Soil conservation, especially on hillsides.
- Improvement of soil fertility.

In order to plan for the use of trees in agroforestry systems, considerable knowledge of their properties is necessary. Desirable information for each species includes its benefits, adaptability to local conditions (climate, soil, and stresses), the size and form of the canopy and root system, and suitability for various agroforestry practices. Some of the most common uses of trees in agroforestry systems are:

- Individual trees in home gardens, around houses, paths, and public places.
- Dispersed trees in cropland and pastures.
- Rows of trees with crops between (alley cropping).
- Strips of vegetation along contours or waterways.
- Living fences and borderlines, boundaries.
- Windbreaks. Agroforestry
- Improved fallows.
- Terraces on hills.
- Small earthworks.

- Erosion control on hillsides, gullies, channels.
- Woodlots for the production of fuel and timber. Some very good food-bearing trees for agroforestry are given in Table 1.

Table 1. **TREES OR LARGE SHRUBS WITH EDIBLE PRODUCTS FOR AGROFORESTRY SYSTEMS**

Species	Common Name	Edibility	Principle Uses
Anacardium occidentale	Cashew	flowers, seeds, fruit	garden, fence, pasture
Annona muricata	Soursop	flowers, fruit	garden, fence, pasture
Borassus aethiopum	Borassus palm	multiple food uses	garden, pasture
Cajanus cajan	Pigeon Pea	seed, leaves	hills, nitrogen fixation, fuel, hedgerows
Carica papaya	Papaya	flowers, fruit	garden, quick shade
Cnidoscolus aconitifolius	Chaya	leaves	rapid hedge
Cocos nucifera	Coconut	multiple food uses	pasture, roadside, construction
Coffea arabica	Coffee	seeds (bean)	hedges, hills, fuel
Gliricidia sepium	Mother of Cacao	flowers	living fence, feed, fuel
Leucaena leucocephala	Leucaena, Ipil Ipil	leaves, young pods	hills, alley cropping, nitrogen fixation, fuel
Manihot esculenta	Cassava	roots, leaves	rapid hedge
Moringa oleifera	Moringa, Drumstick	leaves, flowers, pods	fence, garden
Psidium guajava	Guava	flowers, fruit	pasture, fuel
Sauropus androgynus	Katuk	leaves	hedge, alley cropping
Theobroma cacao	Cacao	pulp, seeds	understory tree, pasture
Yucca guatemalensis	Izote	flowers	hedge
Ziziphus mauritiana	Jujube	flowers, fruit	erosion control, fuel

Non-trees:

Any crop plant can be used in agroforestry systems. The choice of crop plants in designing such systems should be based on those crops already produced in a particular region either for marketing, feeding animals, or for home consumption, or that have great promise for production in the region. In keeping with the philosophy of agroforestry, however, other values to be considered in crop selection include proper nutrition, self-sufficiency and soil protection. Thus, selection of crops requires a judgment based on knowledge of the crops, adaptations, production uses, as well as family needs, opportunities for barter, and markets. Any farm animal can be used in agroforestry systems. The choice of animal will be based on the value the farmer places on animal-derived benefits including income, food, labor, nonfood products, use of crop residues, and manure.

14 & 15

Different agroforestry systems prevalent in the country, shifting cultivation, taungya, alley cropping, wind breaks and shelter belts, home gardens with regional examples

.

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

(i) Improved fallow species in shifting cultivation
(ii) The Taungya system
(iii) Multispecies tree gardens
(iv) Alley cropping (Hedgerow intercropping)
(v) Multipurpose trees and shrubs on farmlands
(vi) Crop combinations with plantation crops
(vii) Agroforestry fuelwood production
(viii) Shelterbelts
(ix) Windbreaks
(x) Soil Conservation hedges

i)Improved Fallow Species in Shifting Cultivation

Fallows are cropland 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 seasons. Shifting cultivation 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 one, two or three crops, after which the land is allowed to rest longer than the period of cultivation. However, during the period of rest the land reverts to some modified form of its original cover

This system is practised extensively in the north-eastern hill region comprising the states of Assam, Meghalaya, Manipur, Nagaland and Tripura and the two Union territories of Arunachal Pradesh and Mizoram and to some extent Andhra Pradesh, Bihar, Madhya Pradesh, Orissa and Karnataka states. It is called **'jhum'** in the north-eastern hill region and **'podu'** in AP and Orissa states and considered most destructive for forest areas.

The main feature of the improved fallow system of agroforestry is that trees and shrubs are not grown with crops on the same plot at the same time. The fallow periods vary from region nto region but are presently becoming shorter due to an increasingly acute land shortage. The best species for the fallow system should induce good nitrogen fixation in the soil.

Species: While 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. Species choice should not be exclusively confined to 'soil improvers'; plants with marketable products should also be considered. 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.

Establishment: Improved fallows can be established in a variety of ways and at various stages of the fallow. Methods might include:

1. Direct seeding of clean tilled, harvested plots;
2. Selective cutting of bush, followed by enrichment planting with tall seedlings;
3. Introducing tall seedlings and cuttings into poor-quality fallows on degraded land;
4. Planting tree seedlings in closely spaced, deep planting holes or furrows within blocks of cleared cropland.

The exact techniques vary with the previous land use, value of the fallow vegetation condition of the land and expected duration of the fallow.

(ii) Taungya System:

The taungya (taung = hill, ya = cultivation) is a Burmese word coined in Burma in 1850s. The taungya system was introduced into India by Brandis in 1890 and the first taungya plantations were raised in 1896 in North Bengal. It is practised in the states of Kerala, West Bengal and Uttar Pradesh and to a lesser extent in Tamil Nadu, Andhra Pradesh, Orissa, Karnataka and the north-eastern hill region. In southern India, the system is called 'kumri'. It is practised in areas with an assured annual rainfall of over 1200-1500 mm.
This is a modified form of shifting cultivation in which the labour is permitted to raise crops in an area but only side by side with the forest species planted by it. This labour is responsible for the upkeep of a plantation. 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. In some cases crops may be grown one year before the trees are planted. A large variety of crops and trees, depending on the soil and climatic conditions.

Crops and trees

a)Trees
Tectona grandis
Bamboo
Santalum album
Tamarindus indica
Acacia nilotica
Acacia mearnsii
Ceiba pentandra
Cashew, Rubber b)
Crops
Millet, pulses, groundnut,cotton

Types of Taungya systems

Taungya systems are of three types:
(a) 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. (b) 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.

(c) 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.

Advantages offered by the taungya system are:
(i) Artificial regeneration of the forest is obtained cheaply
(ii) Problems of unemployment are solved
(iii) Helps towards maximum utilisation of the site
(iv) Low cost method of forest plantation establishment
(v) In every case highly remunerative to the forest departments
(vi) Provision of food crops from forest land (vii) Weed, climber growth etc. is eliminated.

Disadvantages of the taungya system
(i) Loss of soil fertility and exposure of soil
(ii) Danger of epidemics
(iii) Legal problems created
(iv) Susceptibility of land to accelerated erosion increases of human labour.
(v) It is a form of exploitation
The taungya farmers are given the following concessions as a part and parcel of success of the system
(i) Free grazing for animals;
(i) Free timber for house construction and agricultural implements
(ii) Schooling facilities for children
(iii) Monitory loan at nominal interest
(iv) Water supply through excavation of wells and construction of ponds.

iii) Multispecies 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 for cash. Major woody species involved in this system are: Acacia catechu, Areca catechu, Phoenix dactilifera, Artocarpus spp., Cocos nucifera, Mangifera indica, Syzygium aromaticum etc

(iv) Alley Cropping (Hedgerow Intercropping):

Alley cropping, also known as hedgerow intercropping, involves managing rows of closely planted (within row) woody plants with annual crops planted in alleys in between hedges. The woody plants are cut regularly 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. Where nitrogen is required for crop production, nitrogen-fixing plants are the main components of the hedgerows.
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 and on sloping land,

the hedgerows and prunings may help to control erosion. Alley cropping usually works best in places where people feel a need to intensify crop production but face soil fertility problems. This situation is often characteristic of crowded, densely populated areas, but may also occur wherever some farmers wish or forced to increase production on a plot of limited size.

Design: Woody plants are introduced as hedgerows in farm fields to maximise the positive and minimise the negative effects of trees on crop management and yields. 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 actually produce a net increase in yields from croplands. Trees may also provide new products such as fuelwood, fodder or food, in addition to the annual crops.

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 and tillage equipment. Ideally, hedgerows should be positioned in an east-west direction so that plants on both sides receive full sunlight during the day. The spacing used in fields is usually 4 to 8 metres between rows and 25 cm to 2 metres between trees within rows. The closer spacing is generally used in humid areas and the wider spacing in subhumid or semi-arid regions.

The position and spacing of hedgerows may also be affected by slope and the placement and design of soil and water conservation structures when these are combined with alley cropping. On sloping land hedgerows should always be placed on the contour. If this means that they do not have the desirable east-west orientation, then they may need regular thinning to prevent excessive shading of adjacent crops.

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

1. It should have a sparse, small crown to permit sunlight penetration or should resprout rapidly after pruning, coppicing, pollarding or lopping.
2. It should form a deep taproot system with few lateral root branches near the surface so as not to compete with crop roots.
3. It should have shallow lateral roots that are easily 'pruned' by ploughing along the hedgerow, without serious damage to the plants.
4. The leaf litter or some portion of it, should decompose at a rate that makes nutrients available when they are needed in the cropping cycle.
5. Ideally, trees and shrubs used for alley cropping should fix nitrogen and should also produce wood, food, fodder, medicine or other products used by farmers or other local community.
6. The species selected should grow well under the specific limitations of the site such as saline or acid soils, drought, flooding, heavy winds, insect pests or other hazards.

Eg. Cassia siamea, Leucaena leucocephala, Gliricidia sepium, Callianda calothyrsus and Sesbania sesban are commonly used tree species for alley cropping.

v) Multipurpose Trees and Shrubs on Farmlands:

In this system, various multipurpose tree species are scattered haphazardly or according to some systematic patterns on bunds, terraces or plot/field boundaries. 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 tree products and the protective function is fencing, social values and plot demarcation. Examples of multipurpose trees employed in agro forestry are: Leucaena leucocephala, Acacia albida, Cassia siamea, Casuarina equisetifolia, Azadirachta indica, Acacia senegal, Cocos nucifera etc.

(vi) Crop Combinations with Plantation Crops:

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

(a) Integrated multistorey (mixed dense) mixture of plantation crops;

(b) Mixture of plantation crops in alternate or other regular arrangement (c) Shade trees for plantation crops, shade trees scattered; and (d) Intercropping with agricultural crops.

(vii) Agroforestry Fuel wood Production:

In this system, various multipurpose fuelwood/firewood species are interplanted on or around agricultural lands.The primary productive role of this system is to produce firewood; 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.

(viii) Shelter-belt:

These are belts/blocks consisting of several rows of trees established at right angles to the prevailing wind. The purposes are: a) to deflect air currents,

b) to reduce the velocity of prevailing winds,

c) to provide general protection to the leeward areas against the effects of wind erosion,

d) to protect the leeward areas from the desiccating effects of hot wind,

e) to provide food, fodder, timber etc.

The following are the main characteristics of shelter-belts:

i)Shape *and composition:* Shelter-belts have a typical triangular shape. This can usually be brought about by raising tall trees in the centre. ***ii)Density and width:*** A certain degree of penetration by winds is planned as by raising a solid wall, the protection decreases very fast on the leeward side. Shelter-belts up to 50 m width are considered ideal under Indian conditions.

iii)Height and spacing: The ratio of height and width should be roughly 1:10. However, this figure may vary with local conditions.

iv)Orientation: Orientation of shelter-belts depends on the direction and velocity of the prevailing winds. Shelter-belts may be raised in quadrangles if the wind direction tends to change very often.

v)Length: Length is an important consideration as far as shelterbelts are concerned. The minimum length of a shelter-belt should be about 25 times its height, ***vi)Choice of species:*** The following species are recommended:

Grasses: *Saccharum spontaneum, S. munja, Panicum antidotale, Cencnrus* sp.

Shrubs: *Calotropis procera, Clerodendron phlomoides, Cassia auriculata, Dodonaia viscosa*

Trees: *Acacia arabica, A. leucopholea, Dalbergia sissoo, Lannea* *coromandelica, Eucalyptus* spp., *Tamarix, articulata, Parkinsonia aculeata, Prosopis juliflora, Prosopis Spicigera ,Casuarinaequisetifolia.*

ix) Wind-break:

Wind-breaks are strips of trees and/or shrubs planted to protect fields, homes, canals or other areas from wind and blowing soil or sand.
The important reasons for which wind-breaks are planted include:

- ✓ to protect livestock from cold winds
- ✓ to protect crops and pastures from hot, drying winds
- ✓ to reduce/prevent soil erosion ✓ to provide habitat for wildlife
- ✓ to reduce evaporation from farmlands
- ✓ to improve the microclimate for growing crops and to shelter people and livestock,
- ✓ to retard grass fire
- ✓ for fencing and boundry demarcation

When properly designed and maintained , windbreaks reduce the speed of the wind and thus its ability to carry and deposit soil and sand. They also improve growing conditions by decreasing water evaporation from soil and plants and can be used to reduce evaporation from water surfaces, such as irrigation ponds, canals or streams. In addition, wind-breaks can provide wide range of useful products, from poles and fuelwood to fruit, fodder, fibre and mulch.

i) Permeability: *A* wind-break works by filtering and breaking the force of the wind. For most purposes, permeable wind-breaks which allow some wind to pass through are the most suitable.The slight movement of air through the wind-breaks forms a cushion of slow-moving air on both upwind and downwind sides. This deflects the main volume of wind upwards and prevents it from descending for some distance. Thus, the wind velocity in the protected area may be reduced to between 25 and 75 per cent of the wind speed. Dense wind-breaks produce a small area of still air in a narrow strip behind the trees, but further downwind there may be considerable turbulance. However, dense wind-breaks may be desirable when a high level of protection is needed for small areas such as around homesteads and work areas or for vulnerable livestock such as newborn lambs, calves etc. The desired permeability can be obtained by carefully selecting tree shrub species. Species such as *Eucalyptus* and *Casuarina* will form el wind-breaks but most native species are more permeable.

ii)Orientation: For best results, plant wind-breaks at right angles to winds from which protection is needed. Wind-breaks planted north-south are a good compromises as they provide protection from winds coming from the western quarter. They also give better shading of adjacent crops and pastures than wind-breaks planted east-west.
iii)Height: The wind-break height determines the size of the sheltered area. The taller the wind-break, the greater the area it protects. On level ground a windbreak will reduce the speed of wind for about 25 times the tree height on down windside. Maximum reduction of wind speed is in the area 5 to 15 times the tree height away from the wind break. On the upwind side some protection is gained up to a distance of 5 times the tree height away from the windbreak. Thus a wind break 20 m tall will give some protection from 100 m on the upwind side to 500 m on the downwind side.

iv)Length: Wind breaks are most effective when they stretch without major gaps for distances exceeding 12 times the mature height of the trees.

v)Number of rows: A single row wind break should be used only where land is so valuable that only a small amount of space can be spared for tree planting. If a single row wind break is to be planted, tree species that retain their foliage to the ground and give a fairly dense growth should be selected. ***Eucalyptus*** **are generally unsuitable as single-row wind-breaks** because of their habit of losing their lower limbs. The main disadvantage of a single row is that if one tree is lost, gap is created, which reduces the efficiency of the entire wind break. **Wind breaks of three to five rows are more effective** for most farm situations and are less affected by gaps caused by mission trees.Tall growing species should be planted in the centre rows and small bushy species in the outside rows

vi)Tree spacing: Distance between trees varies with the relative importance of the protective versus productive purposes of the wind break. Where the products of wind breaks have a high priority, then land-users may favour greater number of shorter strips and a higher proportion of small trees and shrubs which provide products such as fodder and fuelwood. If the by product is timber, the height of wind breaks and the intervals between them can be increased. When the interest is to protect valuable crops, the wind breaks should be as tall and as far apart as possible to obtain the more protection. In dry areas, individual plants should be widely spaced so that they do not compete with each other for the available soil moisture.

vii)Gaps: Gaps are required for gates and tracks, but because of the funneling effect through gaps, wind velocity in these areas can be substantially increased. In multi row wind breaks this can be eliminated by angling the gap at about 45 degrees to the prevailing wind direction. Alternatively, a few plant, trees or shrubs can be used on either side of the gate or track to broaden the gap and reduce the funneling effect. Other solutions are to plant five or six trees at an angle to the main belt as a wing or to plant a second short row to cover the gaps .

viii)Species: In general, trees with narrow, vertical growth are ideal for wind breaks to minimise the land removed from crop production. Some fast-growing species should be used to establish the desired effect as rapidly as possible. Some of the tree species used for windbreaks are *Eucalyptus, Cassia, Prosopis, Leucaena, Casuarina, Acacia, Grevillea, Syzygium, Dalbergia* etc.

(x) Soil Conservation Hedges: Trees can be planted on physical soil conservation works (grass strips, bunds, risers and terraces) wherein they play two roles: ie., to stabilise the structure and to make productive use of the land they occupy. Stabilisation is through the root system. In some of sloping landscapes of the country, the risers or terraces are densely planted with trees, with multiple use being made of them for fruit, fodder and fuel wood . In this system the major groups of components are: multipurpose and trees and common agricultural species. The primary role of multipurpose 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.*

SILVIPASTURE SYSTEM

The production of woody plants combined with pasture is referred to Silvipasture system. The trees and shrubs may be used primarily to produce fodder for livestock or they may be grown for timber, fuelwood, fruit or to improve the soil. **This system is classified in to three categories** i) Protein bank ii) Livefence of fodder trees and hedges iii) Trees and shrubs on pasture

i) Protein bank

In this Silvipastural system, various multipurpose trees(protein rich trees) are planted on or around farmlands and range lands for cut and carry fodder production to meet the feed requirement of livestock during the fodder deficit period in winter

Example: *Acacia nilotica, Albizia lebbeck, Azadirachta indica, Leucaena leucocephala, Gliricidia sepium, Sesbania grandiflora*

ii) Livefence of fodder trees and hedges

In this system, various fodder trees and hedges are planted as live fence to protect the property from stray animals or other biotic influences.

Example: *Gliricidia sepium, Sesbania grandiflora, Erythrina sp, Acacia sp.*

iii)Trees and shrubs on pasture

In this system, various tree and shrub species are scattered irregularly or arranged according to some systemic pattern to supplement forage production. **Example:***Acacia nilotica, Acacia leucophloea ,Tamarindus indica, Azadirachta indica.*

AGRISILVOPASTURAL SYSTEMS AND OTHER SYSTEMS

The production of woody perennial combined with annuals and pastures is referred Agrisilvopastural system.

This system is grouped into two categories. i) Home gardens ii) Woody hedgerows for browse, mulch, green manure, soil conservation

i) Home gardens

This system is found extensively in high rainfall areas in tropical South and South east Asia. This practice finds expression in the states of Kerala and Tamil Nadu with humid tropical climates and where coconut is the main crop. Many species of trees, bushes , vegetables and other herbaceous plants are grown in dense and in random or spatial and temporal arrangements. Most home gardens also support a variety of animals. Fodder grass and legumes are also grown to meet the fodder requirement of cattle. In India, every homestead has around 0.20 to 0.50 ha land for personal production.

Home gardens represent land use systems involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and livestock within the compounds of individual houses. The whole tree- crop- animal units are being intensively managed by family labour.Home gardens can also be called as **Multitier system** or **Multitier cropping**

Home gardens are highly productive, sustainable and very practicable. Food production is primary function of most home gardens.

Structure of Home Gardens: Home gardens are characterized by high species diversity and usually 3-4 vertical canopy strata. The layered configuration and compatible species admixture are the most conspicuous characteristics of all home gardens. Generally all home gardens consist of a herbaceous layer near the ground, a tree layer at the upper levels and an intermediate layer. The lower layer can be partitioned in to two, the lowermost being at less than 1.0m in height, dominated by different vegetables and the second layer of 1.0 -3.0/m height comprising food crops such as banana, papaya and so on. The upper tree layer can also be divided into two, consisting of emergent , full grown timber and fruit trees occupying the upper most layer of25m height and medium size trees of 10-20m occupying the next lower layer. The intermediate layer of 5-10m height is dominated by various fruit trees.

Choice of species:

a) Woody species : *Anacardium occidentale,Artocarpus heterophyllus, Citrus sp, Psiduim guajava, Mangifera indica, Azadirachta indica, Cocus nucifera,* **b) Herbaceous species:** Bhendi, Onion, cabbage, Pumpkin, Sweet potato,Banana, Beans, etc.

ii) Woody Hedgerows:

In this system various woody hedges , especially fast growing and coppicing fodder shrubs and trees are planted for the purpose of browse, mulch, green manure soil conservation etc. The following species viz., *Erythrina sp, Leucaena luecocephala , Sesbania grandiflora* are generally used.

OTHER SYSTEMS

i) Apiculture with trees: In this system various honey (nector) producing trees frequently visited by honeybees are planted on the boundary of the agricultural field.

ii) Aquaforestry: In this system various trees and shrubs preferred by fish are planted on the boundary and around fish ponds. Tree leaves are used as forage for fish. The main role of this system is fish production and bund stabilization around fish ponds

iii) Mixed wood lots: In this system special location specific multipurpose trees (MPTs) are grown mixed or separately planted for various purposes such as wood, fodder, soil conservation , soil reclamation etc.

16 & 17

Cultivation practices of two important fast growing tree species of the region

1 Tamarind (□□□□□)

Scientific Name : *Tamarindus indica*
Mrathi Name : chinch
Hindi name : Imli
Family : Caesalpinae

Distribution

Tamarind is native to dry savanna of tropical Africa.In ancient times it was introduced to Asia by Arab traders.

Physiognomy

Tamarind is a medium large-sized evergreen tree, up to 24 m in height and 7 m in girth. The bark is brownish or dark grey and fissured longitudinally and horizontally. Leaves are paripinate and 15 cm long. Leaflets vary from 10-20 pairs; oblong and measure 8.30 x 5.10 mm. Flowers are bore in small terminal, dropping racemes on current season's growth. Pods are 7.5 - 20 cm long, 2.5 cm broad and 1 cm thick, more or less constricted between the seeds, slightly curved, brownish - ash in colour. A tree in Urigam. Village (Dharmapuri) possesses long pods measuring 30-45 cm. There are 3 to 12 seeds in each pod which are obovate, oblong, compressed with a shallow, oblong pit on each side of the flat face, 1.5 x 0.8 cm, smooth dark brown and shining. Seeds are contained in loculi, enveloped by a tough, leathery membrane, the so-called endocarp. Outside the endocarp is the light brownish, red sweetish, acidic, edible pulp, traversed by a number of branched, ligneous 'strands. The pod shell is fragile and easily separable.

Phenology

Tamarind flowers from April - July in most areas of South India. Peak flowering occurs during May - June. New leaves appear in May and are closely followed by the flowers and occasionally fresh leaves and flowers are seen in September in Calcutta region. Fruits nature during winter season in South India. Time and duration of anthesis varies with prevailing weather conditions in different locations. Anthesis occurs as early as 5.30 am and continues up to 8.30 am with peak anthesis at 6.30 am.

Silvicultural Characters

It is a light demander; very sensitive to frost; drought resistant. It is deep rooted and windfirm; slow-growing. It coppices fairly well; produces root suckers freely.

Climate and Soil

It is a tree of tropical climate, tolerating temperatures up to *470C* but is very sensitive to frost and fire. Prefers mean annual rainfall of 500 to 1500 mm and tolerates water logging. But also grows well with only 350 mm annual rainfall if watered for establishment. It can be grown under a variety of soils raging from gravelly to deep alluvial. It thrives best on deep alluvial soil with adequate supply of moisture.

Nursery Technique

Pods are collected during February - April. The fruits are dried in sun; the outer shell is removed by hand or by beating with a mallet; the seed is separated from the pulp by hand kneading and washed in water. Washed seeds are dried under shade ad stored. Seeds from crown collection are superior to those of ground collection. About 1800-2000 seeds weigh one kg.

Seeds are normally sown directly in sand medium or polybags. Germination takes place in 510 days and is completed in 30 days. Young plants grow fast on porous soil and a soil mixture of 1: 1: 1 red soil, sand, farmyard manure.

A low cost technology of soaking for 24 hr in a solution prepared by dissolving handful of cow dung or cow's urine (1: 1 in 10: 1 water) results in vigorous seedling to the extent of 75- 80 per cent. One year old seedlings are field planted at a spacing of 10 x 10 m. A full grown tree yields 180-225 kgs of fruit and 80 kg of seeds per tree.

Planting

One year old seedlings are planted at a spacing of7m X 7m in pits. Seedlings are fit for planting out in July to August. .

Utilization

1. All plant parts find some use, but the most useful is the fruit which contains sweetish acidic pulp.
2. The Tamarind of commerce which is widely used for souring curries, sauces, chutneys and certain beverages.
3. The pulp is also employed in medicine. Leaves boiled along with gingelly oil is applied to relieve swelling caused by sprains / fractures and also to relieve pain.
4. Pulp mixed with sugar and made into Tamarind balls is used for seasoning other food. Refreshing acid drink and syrup are also made. Leaves serve as good fodder.
5. Tender leaves, flowers and young seedlings are used as vegetable.
6. Seeds are eaten after roasting or boiling.
7. Powdered seeds are used as cattle feed. Processed seed powder is used in confectionery.
8. Kernels contain a polysaccharide having very good sizing properties and extensively employed as a source of sizing powder in cotton and jute industries.
9. The tree yields valuable timber, hard and difficult to work. The tree is extensively used for avenue planting.

Neem (□□□□□□□)

Scientific Name : *Azadirachta indica*
English name : Neem, Nim, Indian Lilac, Chinaberry
Hindi name : Bal-nimb, Neem, Neim, Nimb, Nind
Family : Meliaceae

Distribution
The tree is believed to be a native of upper Myanmar. Its occurrence in the Siwalik forest of Uttar Pradesh is also considered natural. In India, neem occurs in tropical dry deciduous and thin forests in drier parts upto 1500 m. It is found in almost all states of India.

Physiognomy
A large evergreen tree, it attains a height of 12 to 15 m and occasionally upto 25 m with a clear bole of 3-7.5 m, 1.8-2.8 m girth. It branches early and forms a broad rounded crown of bright green foliage. Bark is moderately thick with scattered, small tubercles between numerous longitudinal and oblique wrinkled furrows, dark grey outside and reddish inside. Leaves are imparipinnate, 20-38 cm long, crowded near the end of branches, leaflets 9-13 nearly opposite, 2.5-7.5 x 1.2-4.0 cm oblique, lanceolate, some times falcate, acuminate, deeply and sharply serrate, glabrous on both surfaces, petioles very short. Inflorescence, an axillary, many flowered panicle, shorter than the leaves. Flowers are white, fragrant. Smelling of honey, shortly pedicelled, bisexual and male flowers occur on the same tree (polygamous). Fruit is a drupe, 12-18 mm long, ovoid-oblong, yellowish/green smooth, dark yellow or purple when ripe, endocarp thin cartilaginous, intercellular spaces appear between the epicarp and the endocarp; their walls break down and form the mucilaginous pulpy mesocarp. Seeds 1-2, reticulate.

Phenology
Neem is almost evergreen but becomes near leafless in dry localities for a short period during February-March. New leaves appear in March-April, before the old ones are shed. Flowering occurs from January-March; in the southern parts of India. In Kerala flowering starts in January, in Karnataka, Tamil Nadu and Andhra Pradesh during February-March; in Central India during the first week of April. Thus flowering is progressively delayed from South to North in the sub-Himalayan area, flowering occurs during the first week of May. Fruiting also follows the pattern of flowering; fruits ripens from June to August. The tree starts fruiting at the age of five years but economic yield of fruits is obtained at the age of 10-12 years. About 3300-4500 seeds weigh one kg and on an average, a medium sized tree produces 37-55 kg fruits.

Silvicultural Characters
It is light-demander. It is sensitive to frost and fire. It is drought-hardy;

Climate and Soil

The species grows on almost all kinds of soils including sandy, clayey, saline, alkaline, black and cotton soils and laterite crusts. However, it does not grow on salty flats, inundated areas and soils with finely divided mica. The tree has a very wide range of climatic adaptability and grows well in areas with a mean annual temperature ranging between O°C to 45°C. It is a light demander species but survives under shade. The rainfall in the areas of its occurrence varies from 450 to 1150 mm.

Nursery Techniques

Physiologically mature seeds with maximum germination capacity and longevity are obtained 10-12 weeks after flowering. The fruit attains peak-green weight and the embryo is fully developed. Green fruits are collected by beating the branches and heaped in the shade by mixing ash, till the seed becomes easily extractable. Seeds are dried in shade for 3-4 days and then sown or stored. Neem seeds do not require any special pre-treatment but seeds do not retain viability very long and have to be sown within 2 or 3 weeks after collection. Depulping and cleaning of seed improve the germination per cent and seeds passed through digestive system of birds show better germination. Seeds are sown in the nursery beds 15-cm apart in rows, 25 cm apart at a depth of 2.5 cm germination normally takes one or two weeks and it may vary from 9 to 55 days. The beds should be sparingly watered and soil kept loose to prevent cutting, excessive water should be avoided.

Seedlings are pricked out to transplanting beds at 15 x 15 cm spacing or to polypots when they are about 5 cm high; neem seedlings do not require shade except during pricking out stage. In frosty localities, the plants should be provided with shelters. Seeds can also be sown in polypots directly.

Planting

Polypot seedlings or root-shoot cuttings are more successful for agroforestry, silvi-pastoral and roadside avenue plantations. One year old seedlings are preferably planted at a spacing of 5 x 5 m.

Utilization

1. For centuries the neem tree, has provided man with twigs for tooth brushes, pharmaceuticals for aches and pains and pest control agents against insects.
2. The drought tolerant neem helps to reduce soil erosion and produces soap, lamp oil, lubricant and lumber. It is also a good shade tree. Every part of neem has its own importance.
3. Neem wood is moderately heavy, stable and resembles mahagoni in appearance; is resistant to fungi and most borers.
4. It is used for making furniture cart axles; yokes, naves and felloes, boards and panels, cabinets, packing cases, ornamental cuttings, ship and boat building, helms, oars, oilmills, cigar boxes carved images, toys, drums and agricultural implements.
5. The leaves are palatable to cattle and buffaloes and constitute a traditional feed in several parts of the country.
6. In Andhra Pradesh, these are regularly fed to cattle and goats to increase secretion of milk immediately after parturition. They are carminative and aid digestion; leaves also used as mulch and manure.
7. Tender leaves in combination with *Piper nigrum* are found to be effective in intestinal helminthiasis. Neem oil and its derivatives are mainly used in soap making and in preparation of toothpaste. Used in pharmaceutical industry.
8. Oil is a remedy in some chronic skin diseases and ulcers and is externally applied for rheumatism, leprosy and sprain.

9. Warm-oil relieves ear trouble, cures dental and gum troubles and provides relief in asthma when taken with betel leaf.
10. Oil is reported to have anti-fertility properties and it possesses antiseptic and antifungal activity.

3. Karanj (□□□□)

Scientific Name : ***Pongamia pinnata***
Hindi Name : Karanj, Paper, Kanji
Family : Leguminosae

Distribution
Pongamia pinnata grows throughout the greater part of the country chiefly along streams and rivers and in beach and tidal forests. It is considered to be a native of the Western ghats, ascending up to an elevation of about 120Om.It is a characteristic tree mixed forests in the Andamans. As a scattered tree it grows in to Sub-Himalayan tract also, ascending in the other hills up to an elevation of about 600m. It has been widely planted in differed parts of the country.

Physiognomy
Full grown *Pongamia pinnata* is a moderate sized tree with a short bole and spreading thick crown. Branches are stout. Leaves are imparipinnate, glabrous and light green leaflets are opposite, without stipules 5-12 cm long and shortly acuminate. The stem bark is thin, smooth, grey and yellowish inside. Pods are indehiscent, turgid almost woody pointed at both ends, 45 cm long, and 1-2 seeded. Seed is compressed, wrinkled, reddish brown and oily.

Phenology
Pongamia pinnata is almost an evergreen tree exception in dry locatitites where it becomes leafless for a short period during May, the leaf shedding occurs several times in a year. Flowering takes place during April to June. Pods ripen from March to May of the following year. Pods are generally collected during December to May and the time of collection in different parts of the country differs according to the climate.

Silvicultural Characters
It is a drought resistant; can withstand frost. It is shade tolerant but does well with full over head light. It is an excellent coppicer; puts forth root suckers readily. It is frequently pollard in South India for green manure

Climate and Soil
Its wide distribution in the country shows that P.pinnata can adapt itself to a spectrum of climatic conditions. In areas where it has been successfully grown, the absolute maximum shade

temperature varies from about 27 to 38°C rainfall from about 500-2500 mm. It can grow on a wide variety of soils, ranging from sandy to black cotton soils, but it grows best on deep and well drained alluvial soils with abundant supply of soil moisture.

Nursery Techniques

Pod collection is done by beating the branches or from ground. The pods are dried in the sun and thrashed to extract the seed, which is dried in shade before storage. Seed yield per tree varies from 9 to 90 kg. Soaking of seeds in cold water for 24 hr hastens and improves germination. About 1200 seeds weigh one kg. Seed length varies from 1.3 cm to 2.30 cm. and seed breath from 0.90 cm to 1.3 cm seed length - breath - ratio varies from 1.0 cm to 107 cm. About 250 g of seed is needed to sow one m of nursery area. Seeds are sown in drills 15 cm apart and at a depth of about 2 cm.

Germination starts in about 10 days and takes about a month, to complete. The percentage of fertility is high and a germination percentage of about 60 to 80 can be expected. One kg seed will produce about 1000 plants. *Pongamia pinnata* can be raised by direct sowing or by planting out of entire plants or stumps. Branch cuttings can also be used for raising this species.

Planting

One year old seedlings which attain a height of about 50-60 cm are planted out. Entire plants or stumps may be used for planting; the use of the latter is more convenient for large scale plantation. For making stumps, plants of about 1-2 cm collar diameter are preferred. Spacing adopted is either 2 x 2m or 3 x 3 m. For avenue planting a spacing of about 8m is adopted. Pits of30 cm3are dug for planting.

Utilization

Leaves of the trees are lopped for fodder, even though their digestibility is poor. Green pods are also fed to cattle in Maharashtra. The seed cake after extraction is used in poultry ration. '

Eucalyptus / Nilgiri (□□□□□□□□)
Scientific Name : ***Eucalyptus tereticornis*** English
Name : Eucalyptus hybrid
Marathi Name : Nilgiri/ Nilgari (□□□□□□□□)
Family : Myrtaceae

Distribution

Native to Australia, E. tereticornis was first introduced in the Nandi hills (Karnataka) by Tiuppu Sultan between 1782 - 1790. Now it is grown over one lakh ha in Peninsular India. Extensive plantations have been raised to meet the needs of fuel wood, small timber and pulpwood in Punjab and Haryana, where area under forest is negligible. It has been planted in strips, 3-6 rows deep along highways, canals and railways. Large scale plantations of the species were taken up in Uttar Pradesh from 1962 onwards.

Physiognomy

It is a tall tree with stout trunk, attains a height of 50 m. It is an evergreen, glabrous tree usually secreting an aromatic gum. The leaves and flowers contain conspicuous oil glands. Leaves of the saplings are generally opposite, sessile, cordate and held horizontal; those of the adult tree as a rule are alternate, petiolate and held vertical. Flowers are borne in umbels usually pedunculate. Calyx tube encloses the ovary which is covered with a deciduous operculum. The operculum is much longer than calyx and is formed by the union of the petals and falls off entire when the stamens emerge. Flowers are white in colour. Fruit consisting of the enlarged calyx-tube is usually hard and woody, full of resin sacs. Seeds are numerous but a large proportion of these is abortive and sterile seeds outnumber fertile ones. Bark is grey, exfoliating in long flakes.

Phenology

It flowers almost throughout the year. The capsules are collected six months after anthesis when they just turn dark brown. If the capsule is left for long on the tree it will burst and shatter the seeds. Hence capsules are collected and kept in trays / tarpaulins. After sun-drying for 3 or 4 days, the empty capsules are removed. Mature seeds are dark brown / black in colour. The seeds retain viability for up to 5 years.

Silvicultural Characters

It is a light demander. It produce good coppices freely and vigorously. It is a fast growing species and adaptability to a wide range of soil and climatic condition

Climate and Soil

It grows up to an altitude of 500 m. It is sensitive to frost. It grows in alluvial, black cotton, gravelly, lateritic, skeletal rocky and murram soils and even on shifting sand dunes. Highly calcareous, very saline and alkaline soils, clay and kantar pan is limiting. Deep, fertile and well-drained loamy soil gives best growth. Temperature range tolerated is 0-48°C. It is suited for the plains receiving a rainfall of 800-1000 mm. The tree prefers sandy loam to loamy soils within a pH range of6.00 - 7.5.

Nursery Techniques

Seeds are sown in raised beds measuring 1 x 1 x 0.15 m. after wetting the bed, sieved seeds @ 5 g m-2 are mixed with a small quantity of sand and evenly spread on the bed. The seeds are covered with a film of soil. The nursery beds need to be kept moist by watering at least twice daily. A mulch of hay prevents soil erosion during watering. Watering is done through a fine rose. BHC 10% has to be applied on the bed to prevent ants/termites. Five and 10 days after sowing 2% copper fungicide must be applied. Germination starts on the 5thday. Since seedlings are sensitive to extreme sunlight, the bed has to be protected by a shade-screen during the first fortnight. Thirty day old seedlings are gently lifted from the bed and containerized in 200 gauge polypots measuring 20 x 10 cm. The polypots are filled with 4: 1:1 mixture of red soil, sand and FYM. After wetting the filled polybags seedling are pricked one per polypot. The pricked out seedlings should be provided shade for a week and watered twice a day. Six month old seedlings are used for planting. The containers must be shifted once every fortnight from the second month to prevent rooting.

Planting

The seedlings are field planted at a spacing of 2 x 2 m in pits measuring 30 cm3. Quality of seedlings is determined by the thickness of the root collar region than by height. The trees are felled at the end of seven years. Thereafter two coppices are taken at intervals of five year each. Coppice management is important in eucalyptus. Hundreds of new shoots develop on the margin of the cut stem. Felling of the trees prior to or immediately after the monsoon helps in rapid callus formation and thicker coppice shoots. Care should be taken to fell the trees with a gentle slope at the cut so that rainwater does not collect as a pool and cause decay of the callus tissue. Though hundreds of coppice shoots develop yet only four to five stems ultimately remain on the stump and the others are edged out in natural competition. There is no need to manually regulate the number of coppices as nature itself does the job. The health and number of coppice stems are positively related to the diameter of the stump. The productivity of coppice plantation is generally higher by 20 -25 % than the first seedling plantation. At the end of the second coppice growth it is necessary to uproot the roots. Its rotation is about 8 - 10 years. The productivity of rainfed plantations in Tamil Nadu Plains ranges from 50 -75 t per ha at the end of seven years. The ratio of first, second and third harvests is 1:1.2:0.8.

Utilization

1. Eucalyptus wood is the main stay of paper industry in Tamil Nadu.
2. Currently, it is used for making packing cases and 70% of the requirement in Himachal Pradesh for apple transport is met by this species.
3. Leaves contain oil.
4. Bark yields oxalic acid.
5. It is preferred by the farmers by virtue of several desiderata like (i) fast growth; (ii) not browsed by cattle; (iii) immunity to pests and diseases; (iv) good coppicing ability.

□□□□□ Acacia

Scientific Name : *Acacia nilotica*
English Name : Indian gum arabic tree
Marathi Name : Babul/ □□□□□
Hindi Name : Babul
Family : Mimosae

Distribution

Babul is indigenous to the Western part of the India- Gangetic plains and the Northern part of Deccan plateau, including Andhra Pradesh, Maharashtra, Rajasthan and Gujarat. It is widely planted, or self - sown throughout the hot regions of India, viz., Punjab, Haryana, Uttar pradesh, Madhya pradesh and Karnataka. It is an important constituent of southern dry mixed deciduous tropical forests, Northern and Southern tropical thorn forests of India; at an elevation range of 200-500 m.

Physiognomy

It is a moderate - sized, almost evergreen tree with a short trunk, a spreading crown, and feathery foliage. Bark dark brown, nearly black, pinkish brown and hard inside, with regular deep longitudinal fissures which very often run spirally up the tree. Young branches green, pubescent. Stipulate spines straight, white, up to 2 inches long, variable, sometimes absent in old trees. The tree varies much in size, remaining little more than a shrub in some localities, and in others attaining a height of 50 to 60 ft. or even more, and occasionally a girth of 8 to 10 ft.

Phenology

The young leaves appear from March to May, the old leaves commencing to fall before they appear. Flowering is most general in the rainy season, from June to September, but trees may be found in flowers as late as December or January. The time of fruit ripening varies according to locality, but is usually from April to June.

Silvicultural Characters

It is drought-resistant; frost-tender. It is strong light-demander. It's coppicing power is very variable, generally poor.

Climate and Soil

A nilotica can grow on a variety of soils, provided sufficient moisture is available. It prefers well drained fresh alluvial sandy loam soil in riverain tracts, though it can grow on clay and black cotton soil also. It can stand mild soil salinity provided sufficient moisture is available. In its natural habitat, average rainfall is 400 to 1500 mm; fairly drought resistant, but thrives best in areas with 500-1250 mm.

Nursery Technique

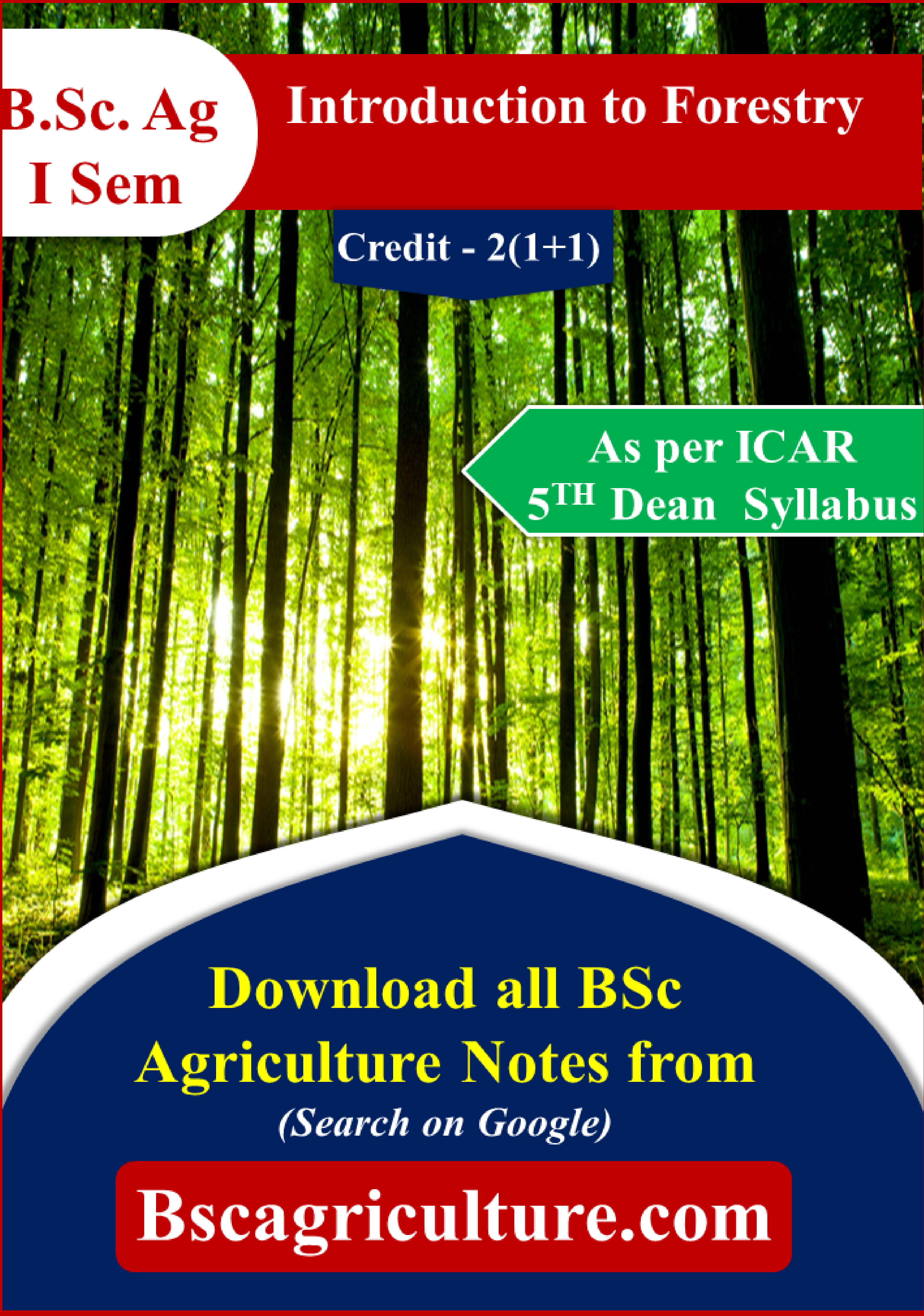
Babul seedlings are raised in polythene bags (5 cm x 22 cm, 150 -200 gauge). Treated seeds are sown, about 1.5 cm deep, 2-3 seeds in each bag in February - March (or May, for freshly collected seed) and regularly watered and weeded. Excessive watering should be avoided; shading is necessary to avoid surface cracking.

Planting

Seedlings are fit for planting out in July - August of the same year (when 3-4 months old). For obtaining bigger plants, seeds is sown in June - July in bigger bags and one year old seedlings are planted out. It's rotation is 30 years for timber and 15-20 years for tannin; it yields 23.02 m3 wood per ha. At the age of 30 years and 8-10 tonnes of pods per ha.

Utilization

1. Leaves and pods are widely used as fodder.
2. It is an extremely valuable source of fuel wood and charcoal of excellent quality.
3. General utility of timbers for construction of carts, wheels, agricultural tools and implements, doors, windows, mine props, fencing materials etc.
4. Bark is one of the best tanning materials of Northern India.
5. Babul gum is used in inks, paints, matches and confectionery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