**INTRODUCTION TO FORESTRY**

**Course no. - ASIF1201**

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**STUDY MATERIAL**



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**Chapter 1**

**Introduction**

Forests cover a third of all land on Earth, providing vital organic infrastructure for some of the planet's densest, most diverse collections of life. They support countless species as well as 1.6 billion human livelihoods, yet humans are also responsible for 32 million acres of deforestation every year. Forest is very important life supporting system on earth particularly for human beings and his animal.

Forest: The word forest is derived from the Latin word "foris" means the vegetation outside the village boundary or away from inhibited land.

Forestry: Forestry is defined as the theory and practices all its constitutes the creation, convention and scientific management of forest and the utilization of their resources.

**Role or Importance of forests**

**1. They help us breathe (release oxygen)**

Forests pump out the oxygen we need to live and absorb the carbon dioxide we exhale (or emit). Just one adult leafy tree can produce as much oxygen in a season as 10 people inhale in a year. Planktons are more prolific, providing half of Earth's oxygen, but forests are still a key source of breathable air.

**2. Rich source of Biodiversity**

Nearly half of all known species live in forests, including 80 percent of biodiversity on land. That variety is especially rich in tropical rain forests, from rare parrots to endangered apes, but forests teem with life around the planet: Bugs and worms work nutrients into soil, bees and birds spread pollen and seeds, and keystone species like wolves and big cats keep hungry herbivores in check.

**3. People live there, too (Habitat for aborigines or natives)**

Some 300 million people live in forests worldwide, including an estimated 60 million indigenous people whose survival depends almost entirely on native woods. Many millions more live along or near forest fringes, but even just a scattering of urban trees can raise property values and lower crime.

**4. They keep us cool (Reduce atmospheric temperature)**

By growing a canopy to hog sunlight, trees also create vital oases of shade on the ground. Urban trees help buildings stay cool, reducing the need for electric fans or air conditioners, while large forests can tackle daunting tasks like curbing a city's "heat island" effect or regulating regional temperatures.

**5. They keep Earth cool (reduce green house gases)**

Trees also have another way to beat the heat: absorb CO2 that fuels global warming. Plants always need some CO2 for photosynthesis, but Earth's air is now so thick with extra emissions that forests fight global warming just by breathing. CO2 is stored in wood, leaves and soil, often for centuries

**6. They make it rain**

Large forests can influence regional weather patterns and even create their own microclimates. The Amazon, for example, generates atmospheric conditions that not only promote regular rainfall there and in nearby farmland, but potentially as far away as the Great Plains of North America.

**7. They fight flooding**

Tree roots are key allies in heavy rain, especially for low-lying areas like river plains. They help the ground absorb more of a flash flood, reducing soil loss and property damage by slowing the flow.

**8. They reduce toxicity**

On top of flood control, soaking up surface runoff also protects ecosystems downstream. Modern storm water increasingly carries toxic chemicals, from gasoline and lawn fertilizer to pesticides and pig manure that accumulate through watersheds and eventually create low-oxygen "dead zones."

**9. They refill aquifers**

Forests are like giant sponges, catching runoff rather than letting it roll across the surface, but they can't absorb all of it. Water that gets past their roots trickles down into aquifers, replenishing groundwater supplies that are important for drinking, sanitation and irrigation around the world.

**10. They block wind**

Farming near a forest has lots of benefits, like bats and songbirds that eat insects or owls and foxes that eat rats. But groups of trees can also serve as a windbreak, providing a buffer for wind-sensitive crops. And beyond protecting those plants, less wind also makes it easier for bees to pollinate them.

**11. They keep dirt in its place**

A forest's root network stabilizes huge amounts of soil, bracing the entire ecosystem's foundation against erosion by wind or water. Not only does deforestation disrupt all that, but the ensuing soil erosion can trigger new, life-threatening problems like landslides and dust storms.

**12. They clean up dirty soil**

In addition to holding soil in place, forests may also use phyto-remediation to clean out certain pollutants. Trees can either sequester the toxins away or degrade them to be less dangerous. This is a helpful skill, letting trees absorb sewage overflows, roadside spills or contaminated runoff.

**13. They clean up dirty air**

We herald houseplants for purifying the air, but don't forget forests. They can clean up air pollution on a much larger scale, and not just the aforementioned CO2. Trees catch and soak in a wide range of airborne pollutants, including carbon monoxide, sulfur dioxide and nitrogen dioxide.

**14. They muffle noise pollution**

Sound fades in forests, making trees a popular natural noise barrier. The muffling effect is largely due to rustling leaves plus other woodland white noise, like bird songs — and just a few well-placed trees can cut background sound by 5 to 10 decibels, or about 50 percent as heard by human ears.

**15. They feed us (source of food and feed)**

Not only do trees provide fruits, nuts, seeds and sap, but they also enable a cornucopia near the forest floor, from edible mushrooms, berries and beetles to larger game like deer, turkeys, rabbits and fish.

**16. They give us medicine.**

Forests provide a wealth of natural medicines and increasingly inspire synthetic spin-offs. The asthma drug theophylline comes from cacao trees, for example, while a compound in eastern red cedar needles has been found to fight MRSA, a type of staph infection that resists many antibiotic drugs. About 70 percent of all known plants with cancer-fighting properties occur only in rain forests.

**17. They help us make things like timber**

Where would humans be without timber and resin? We've long used these renewable resources to make everything from paper and furniture to homes and clothing, but we also have a history of getting carried away, leading to overuse and deforestation. Thanks to the growth of tree farming and sustainable forestry, though, it's becoming easier to find responsibly sourced tree products.

**18. They create jobs**

More than 1.6 billion people rely on forests to some extent for their livelihoods, according to the U.N., and 10 million are directly employed in forest management or conservation. Forests contribute about 1 percent of the global gross domestic product through timber production and non-timber products, the latter of which alone support up to 80 percent of the population in many developing countries.

**19. They create majesty (Natural beauty for recreational purpose)**

Natural beauty may be the most obvious and yet least tangible benefit a forest offers. The abstract blend of shade, greenery, activity and tranquility can yield concrete advantages for people, however, like convincing us to appreciate and preserve old-growth forests for future generations.

**20. They help us explore and relax.**

**Basic terms related to forest**

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

**Age classification:**The division of a crop according to difference in age **OR** the allotment of woods to age classes. **Age crop:**The age of a regular crop corresponding to its crop diameter **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.

Analog forestry : A management focus that seeks to establish a tree-dominated ecosystem that is similar in architectural structure and ecological function to the naturally occurring climax and sub-climax vegetation community.

Bamboo cultivation – Farming and harvesting bamboo for commercial purposes such as construction.

**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.

**Bole:**The main stem of a tree.

**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)

Community forestry – Combination of forest conservation with rural development and poverty reduction objectives, accomplished through instating a legal framework that favors profitable and sustainable forest management

**Coppice:**When certain plants or seedling are cut from near ground level, they produce a flush of fresh shoots. This is known as coppicing

**Coupe:** A felling area, usually one of an annual series unless otherwise stated. Preferable numbered with Roman numbers as, I, II, III etc.

**Crown:** The upper branchy part of the tree above the bole.

**Dendrology:**The identification and systematic classification of trees.

[Eco forestry](https://en.wikipedia.org/wiki/Ecoforestry) – emphasizes practices which strive to protect and restore ecosystems

Energy forestry – includes specifically managing for the production of energy from biomass or biofuel derived from a fast-growing species of tree or woody shrub

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

Forest ecology – studies the patterns and processes of a forest ecosystem

Forest economics–studies the impact of economics on forest management decision

Forest hydrology – embodies the effects of changes in forest land use on the movement, distribution, and quality of water in the ecosystem.

[Forest management](https://en.wikipedia.org/wiki/Forest_management) – comprises the overall administrative, economic, legal, and social aspects of forest regulation

Forest mensuration – incorporates quantitative measurements of the forest stand to determine stand timber volume and productivity/health, and provides a basis off which management decisions can be made

Forest pathology – research of both biotic and abiotic maladies affecting the health of the forest or tree, primarily fungal pathogens and their insect vectors

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.

Hardwood timber production – process of managing stands of deciduous trees to maximize woody output

**Log:** The stem of a tree or a length of stem or branch after felling and trimming.

**Logging:**Operation comprising felling of trees, limbing, bucking and transportation of the resulting product out of the forest timber harvesting (Bucking-Act of being)

**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.

**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.

**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)**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. **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. **Pruning:** Means the cutting of branches from the bole in order to maintain the quality of timber. **Raft:**An assemblage of logs, timbers or bamboos tied together or enclosed within a boom for transport by floating

**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.

**Reserved forests:**an area so constituted under the Indian Forest Act or other Forests law.

**Scrub:**Inferior growth consisting chiefly of small or stunted trees and shrubs.

**Seed orchards:**are plantations which may raised exclusively with the aim of producing seed.

**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.

**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:

Short rotation coppice (SRC) – focus on species that are able to naturally regenerate through [stump sprouts](https://en.wikipedia.org/wiki/Living_stump) to maximize economic productivity

Short rotation forestry – managing a forest that utilizes fast-growing species as a bio-based [energy crop](https://en.wikipedia.org/wiki/Energy_crop) for use in power stations, alone or in combination with other fuels such as coal

[Silviculture](https://en.wikipedia.org/wiki/Silviculture) – is the art and science of controlling the establishment, growth, composition, health, and quality of forests to meet specific objectives

**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.

Social forestry – addresses human-forest interactions, and the importance of community-based [natural resource management](https://en.wikipedia.org/wiki/Natural_resource_management).

**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.

**Succession:** The gradual replacement of one community by another in the development of vegetation towards a climax. Sustainable forest management – emphasizes practices that maintain forest biodiversity, productivity, regeneration capacity, and vitality, while continuing to fulfill relevant ecological, economic and social functions

Sustainable forestry – emphasizes forest management for long-term environmental, social, and economic [sustainability](https://en.wikipedia.org/wiki/Sustainability).

**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 form 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.

**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.

Tree breeding – method of genetically modifying/selecting forest stock for improved growth or vigor characteristics

Tree farm – a forest or woodland owned privately where timber crop production is a major management goal

**Un classed forest:** Forest land owned by Government but not constituted in to a reserved, village or protected forest.

Urban forestry – entails the care and management of urban tree populations for the purpose of improving the urban environment

**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.)

World forestry – examines forest conservation at a global level.

**Branches of Forestry**

Mainly, the forestry has been grouped as follows:

**1. Basic Forestry**

**2. Applied Forestry**

1. Basic Forestry: Basic Forestry deals with the theory and practice of constitution and management of forests and utilization of their products. Agriculture is the study of science and art of production of plants and animals used by man In India, the geographical, areas is about 32,80,500 km2. The forests occupy about 7,50,000 km2. (22.9% approximately) whereas agricultural (cultivated) area is about 46% However, agriculture is the largest enterprise in India. Nearly, 70% of the population is employed in this profession. But unfortunately, in spite of this, it is not able to meet the requirements of ever-increasing population.  Forestry, just like agriculture, is a good professional with the difference of long life-span.

**Basic Forestry has the following Branches:**

**A) Silviculture:** This refers to certain aspects to theory and practice of raising forest, crops, methods of raising tree, their growth and after-cares up to the time of final harvesting. However, in simple words, it is the cultivation of forest trees.

**B) Forest Mensuration:** In simple language, it is the measurement of forest produce. However, it is defined as the determination of dimensions (e.g. height, diameter, volume, etc.) from, volume, age and increment of single trees, stands or whole woods, either standing or after felling. It concerns with linear area, volume and weight measurements.

**C) Silvicultural Systems:** A Silvicultural system can be defined as a method of Silvicultural procedure worked out in accordance with accepted sets of Silvicultural principles by which crops constituting forests are tended, harvested and replaced by new crops of distinctive forms.

**D) Forest Management:** It is the practical application of science, technique, and the economics to a forest estate for the production of some wanted results.  In actual sense, it is the application of business methods to the operation of a forest estate. The Society of American Foresters (SAF) has described it as an application of business methods and technical forestry principles to the operation of a forest property.

**E) Forest Utilization:** It is a branch of forestry concerned with the harvesting, conversion, disposal and use of forest produce (British Common Wealth Forest Terminology, 1953.).According to SAF (1983) it is a branch of forestry concerned with the harvesting, any necessary processing, and delivery to the consumer of forest produce.

**F) Forest Law:** Law includes any rule of action. The rules and law imposed by the state up on the actions of its citizens for the breach of which they are punishable. Forest law is classified as:  
a) Constitutional laws

b) Public laws

c) Private laws;

Very essential for protection of forest; Some terms -  Forest offence / Forest right / Forest settlement  
d) Forest wild life Act WL (protection ) Act 1972 Animals / bird.

**G) Forest Policy:** Branch of forestry concerned essentially, with social and economic aims underlying forest management and forestry development (SAF - 1983)

**2.  Applied Forestry:** This includes those subjects which how the references to other subject but make the essence of, forestry

a) Dendrology

b)Forest Ecology

c)Forest Economy

d)Forest Entomology

e)Forest Fire

f) Forest Genetics

g)Forest Pathology

h)Forest Seed technology

i) Forest soils

j) Forest statistics

k)Forests surveying

l) Remote sensing

m)Social Forestry-Social Resent

i. Agroforestry

ii. Forestry Extension

iii. Afforestation

iv. Recreation Forestry etc.

**Some Other Forestry Branches:**

1. Aesthetic forestry

2. Commercial Forestry

3. Community Forestry

4. Extensive Forestry

5. Farm Forestry

6. Extensive Forestry

7. Multiple use Forestry.

## Relation with other branches of forestry

**Forest Mensuration:** Silviculture deals with raising of forest crops, forest mensuration deals with measurement of diameter and heights of crop so produced, calculation of its volume, age, etc., for sale and research to decide the best treatment to be given to the crop while it is being raised.

**Forest Utilization:** Silviculture deals with cultivation of forest crops, forest utilization is concerned with the harvesting and disposal of crops so produced

**Forest Economics:** Silviculture deals with cultivation of forest crops, forest economics works out the cost of production including rental of land and compound interest on capital spent in raising the crop. It compares the cost of production by different methods and then decide the most profitable method of raising that crop.

**Forest Management:** It manages forest crops according to the dictates of the policy and prescribes the time and place where the silvicultural techniques and operations are carried out to attain the goal of management.

**Forest Protection:** A knowledge of the injuries caused to forests by the local human and animal population, both domestic and wild, insects, fungi and other adverse climatic factors and preventive and remedial measures to counteract them, whereas silviculture is concerned with raising forest crops

**Forest Ecology:** It is concerned with forest ecosystem. It deals with different species of flora and fauna, whereas silviculture deals with their cultivation and maximization of their production.

**Other Terminologies on Forestry**

Dendrology – involves the study and identification of economically useful tree species

Energy forestry – includes specifically managing for the production of energy from biomass or biofuel derived from a fast-growing species of tree or woody shrub

Forest ecology – studies the patterns and processes of a forest ecosystem

Forest economics – studies the impact of economics on forest management decisions

Forest hydrology – embodies the effects of changes in forest land use on the movement, distribution, and quality of water in the ecosystem

Forest mensuration – incorporates quantitative measurements of the forest [stand](https://en.wikipedia.org/wiki/Stand_level_modelling) to determine stand timber volume and productivity/health, and provides a basis off which management decisions can be made

Forest pathology – research of both biotic and abiotic maladies affecting the health of the forest or tree, primarily fungal pathogens and their insect vectors

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World forestry – examines forest conservation at a global level

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Bamboo cultivation – farming and harvesting bamboo for commercial purposes such as construction.

Community forestry – combination of forest conservation with rural development and poverty reduction objectives, accomplished through instating a legal framework that favors profitable and sustainable forest management

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Hardwood timber production – process of managing stands of deciduous trees to maximize woody output

Tree breeding – method of genetically modifying/selecting forest stock for improved growth or vigor characteristics

[Mycoforestry](https://en.wikipedia.org/wiki/Mycoforestry) – ecological forest management system implemented to enhance forest ecosystems and plant communities through the introduction of mycorrhizal and saprotrophic fungi

[Permaforestry](https://en.wikipedia.org/wiki/Permaforestry) – approach to the wildcrafting and harvesting of the forest biomass that uses cultivation to improve the natural harmonious systems. It is a relationship of interdependence between humans and the natural systems in which the amount of biomass available from the forest increases with the health of its natural systems.

[Plantation forestry](https://en.wikipedia.org/wiki/Plantation#Forestry) – industrial plantations are established to produce a high volume of wood in a short period of time. Some plantations are managed by state forestry authorities (for example, the Forestry Commission in Britain) and others by paper and wood companies (such as Weyerhaeuser, Rayonier and Plum Creek Timber in the United States, Asia Pulp & Paper in Indonesia).

Short rotation forestry – managing a forest that utilizes fast-growing species as a bio-based [energy crop](https://en.wikipedia.org/wiki/Energy_crop) for use in power stations, alone or in combination with other fuels such as coal

Short rotation coppice (SRC) – focus on species that are able to naturally regenerate through [stump sprouts](https://en.wikipedia.org/wiki/Living_stump) to maximize economic productivity

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Tree farm – a forest or woodland owned privately where timber crop production is a major management goal

**Questionnaires'’**

**Long type question**

1. Define afforestation and reforestation.
2. What is forest and describe its role or importance.
3. Briefly discuss the branches of forestry and its relation to other branches.

**Short type question**

1. Taungya system is first evolved in
2. The stem of a tree or a length of stem or branch after felling and trimming is called as

**Chapter 2**

**Silviculture**

Silviculture has been defined by different authors. According to Toumey and Kortistian Silviculture is the branch of forestry which deals with the establishment, development ,care and reproduction of timber. According to Indian forest and Forest products terminology, Silviculture is the art and science of cultivating forest crops. Silvics is the study of life history and general characteristics of forest trees and crops with particular reference to environmental factors, as the basis for the practice of silviculture.

The practice of silviculture includes regeneration area, selection of suitable species, creation and maintenance of forest, improving their condition, controlling their composition, restocking the under stock area, improvement of site conditions, tending operations, etc.

**Objectives of Silviculture**

The main objective are summarized below

* Production of species of economic value
* Production of larger volume per unit area per increasing the productivity of the forest
* Production of quality timber
* Reduction of rotation
* Raising forest in the blank area/unproductive areas
* Creation of manmade forest in place of natural forests
* Introduction of exotics
* Control of stand structure
* Control of stand density
* Control of composition
* Conservation of site quality
* Increase employment opportunities
* Increase the production of fuel and fodder
* Development of forest industries
* Derive environmental benefits
* Protection and reduction of losses

**Classification of Forests**

Forests can be classified on the basis of:

* Age
* Method of regeneration,
* Composition
* Ownership
* Object of Management
* Growing Stock.

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

A) Even Aged Forest:

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

B)  Un-Even Aged Forests:

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

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

A. High Forest: When regeneration is obtained from seed

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

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

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

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

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

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

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

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

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

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

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

A. Government Forests:

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

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

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

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

B. Private Forests

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

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

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

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

**Classification of major kinds of forests of the world**

Types of forests are classified differently from one and another depending upon the species developed with the age of forests, soil found in those forests, the density of trees and history of the geological region. So forests are divided into following main types:

* Tropical forest and Sub tropical forest
* Plantations
* Boreal Forest
* Temperate forest
* Seasonal or monsoon forest

## Tropical Forest and Subtropical Forests

Tropical and subtropical forests, also known as rainforests or tropical rainforests, are lavish and ample forests with broad leafed trees.

They are mostly found at lowlands near the equator. These forests are evergreen forests and remain the same throughout the year. These forests form a dense and thick upper layer of foliage (canopy). Tropical forests are of vegetations type, and are home to more than half of the species of animals and plants dwelling on the earth.

Tropical forests occur near the equator and are the most ecologically rich of all forest types. They are also one of the most threatened forest types due to logging and clearance for agriculture (see the section on ‘Deforestation’).

Rainforests are forests with high rainfall and humidity. Although they are perhaps the tropical forest type about which there is the most publicity, tropical rainforests are only one of many different tropical forest types. Other tropical forest types include dry coastal forests, Montana cloud forests, and semi-arid savannah woodlands.

"A major characteristic of tropical forests is their distinct seasonality: winter is absent, and only two seasons are present (rainy and dry). The length of daylight is 12 hours and varies little. As a consequence of the long growing season and hours of daylight all year long, tropical forests regenerate quickly. Despite the regenerative capacity of tropical rainforests, timber harvest in the tropics is rarely followed by regeneration. Conversion to agriculture is often permanent or results in soil erosion. Timber harvest contracts are usually short term and provide little or no incentive for timber companies to replant. So little reforestation has been done in the tropics that many people believe these forests cannot be restored. However, these forests can be restored and there are many successful examples in India, Indonesia, and the Caribbean."

**Tropical forest types**

Within the tropical forest biome, there are several forests types, which are determined by seasonal distribution of rainfall:

* Evergreen rainforest: no dry season.
* Seasonal rainforest: short dry period in a very wet tropical region (the forest exhibits definite seasonal changes as trees undergo developmental changes simultaneously, but the general character of vegetation remains the same as in evergreen rainforests).
* Semi-evergreen forest: longer dry season (the upper tree storey consists of deciduous trees, while the lower storey is still evergreen).
* Moist/dry deciduous forest (monsoon): the length of the dry season increases further as rainfall decreases (all trees are deciduous).

### Temperate Forests

Temperate forests can be found on both hemispheres on latitude approximately 25 to 50 in regions of northeastern Asia, North America, western and central Europe and can be categorized as deciduous as well as evergreen.

The interesting thing about these forests is that they have all four seasons; summers, spring, winter and fall. Soil of these forests is fertile and enriched.

Trees of these forests can be categorized as broad leafed trees including those which change their foliage every year like oak, maple, beech, hemlock, cotton wood, elm and many more of same kind. Animal species found in these forests are birds, rabbits, squirrels, wolf, black bear, mountain lion and bob cat. Temperate forests occur in eastern North America, northeastern Asia, and western and central Europe. Well-defined seasons with a distinct winter characterize this forest biome. Only scattered remnants of original temperate forests remain. Well-defined seasons with a distinct winter characterize this forest biome. Moderate climate and a growing season of 140-200 days during 4-6 frost-free months distinguish temperate forests. Because the growing season is shorter, temperate forests regenerate more slowly than tropical forests. Tree species include characteristic broadleaved species which lose their foliage annually such as oak, hickory, beech, hemlock, maple, basswood, cottonwood, elm, willow, and spring-flowering herbs. At higher elevations, in areas with lower temperatures, and in poorer soils, temperate conifers such as pines and firs predominate. Fauna is represented by squirrels, rabbits, skunks, birds, deer, mountain lion, bobcat, timber wolf, fox, and black bear.

**Temperate forest types**

Within the temperate forest biome, there are several forest types, which are determined by seasonal distribution of rainfall

* Moist conifer and evergreen broad-leaved forests: wet winters and dry summers (rainfall is concentrated in the winter months and winters are relatively mild).
* Dry conifer forests: at higher elevation zones; low precipitation.
* Mediterranean forests: precipitation is concentrated in winter, less than 1000 mm per year.
* Temperate coniferous: mild winters, high annual precipitation (greater than 2000 mm).
* Temperate broad-leaved rainforests: mild, frost-free winters, high precipitation (more than 1500 mm) evenly distributed throughout the year.

**Boreal forests**

Boreal forests, or taiga, represent the largest terrestrial biome. Boreal (meaning northern) forests can be found in areas with shorter, warm summers and long winters; there are boreal forests in Europe, Asia, Siberia, and North America. Because of the cold climates, plant life in the boreal forest is sturdy, consisting mainly of evergreens and other resilient vegetation.

Boreal forests occur between latitudes of 50 and 60 degrees north. They are found in the broad belt of Eurasia and North America: two-thirds of the boreal forests are in Siberia with the rest in Scandinavia, Alaska, and Canada. Seasons are divided into short, moist, and moderately warm summers and long, cold, and dry winters. The length of the growing season in boreal forests is 130 days at most.

Because boreal forests are found in regions with short summers and long winters, these forests regenerate slowly. However, plant life in these cold areas is sturdy, consisting mainly of evergreens and other resilient vegetation. The forest canopy is so dense that little light reaches the forest floor, thus the vegetation on the forest floor is thin. The forests consist mostly of evergreen conifers with needle-like leaves, such as pine (Pinus), fir (Abies), and spruce (Picea). There are also deciduous genera such as birch (Betula) and poplar (Populus).

Temperatures are very low. Precipitation is primarily in the form of snow, 40 to > 100 cm annually. Soil is thin, nutrient-poor, and acidic. Canopy permits low light penetration, and as a result, understory is limited. Flora consists mostly of cold-tolerant evergreen conifers with needle-like leaves, such as pine, fir, and spruce. Fauna include woodpeckers, hawks, moose, bear, weasel, lynx, fox, wolf, deer, hares, chipmunks, shrews, and bats. Boreal forests are also known by name Taiga. The word ‘Boreal’ means northern, these forests are occupying about 17% of the land.

This type of forest can be easily found on latitude 50 to 60. Temperature in these forests is usually low, as the canopy allows very low sunlight to penetrate.

Low penetration of light along with low temperature is responsible for limited under story. Soil of these forests is poor- nutrient and thin. Trees like pine, spruce and fir are most likely to be found in these forests which are cold-tolerant and evergreen in nature.

A number of animal species also found in these forests which includes bears, bats, woodpecker, hawks deer, fox and many other that could tolerate low temperature.

**Plantations**

Plantations can also be classified as a type of forest. Plantations are actually a large farm, piece of land or estate that is used for cultivation. Plantations are usually adopted in tropical and subtropical regions.

In these farms and lands cultivation of different crops is done on a large scale for international or distant markets rather than for local or domestic consumption. These crops include rubber seeds,

oil seeds, sugar cane, cotton, tobacco, coffee and sisal. Plantations done for industrial purpose is called forestry. It is it done to get larger amount of wood in a shorter span of time.

**Natural or ‘frontier’ forests**

1. [Natural forests](http://www.forestfacts.org/l_3/forests_1.htm#3p1)

2. Frontier forests

3. The ’pristine’ Amazon forest

Another classification of forests makes a distinction between ‘natural’ forest and forest plantations. There is some controversy concerning the definitions of both "natural forest" and "forest plantation." The controversy reflects the differing interests of groups who have a stake in the future of forests. These ‘stakeholders’ include—but are not limited to—forest industry interests who see forests as a source of raw material to produce timber or pulp; conservation groups who seek to maintain the biodiversity and environmental values of natural forests; people and institutions seeking to mitigate global warming by using forests for carbon sequestration (storage); and the representatives of landless people in some countries who see forest land as potential agricultural land."

#### Natural forests

There is very little untouched forest left in the world. Almost every corner of the planet is directly or indirectly influenced by human activity. Forests are either directly affected by human activities such as cutting, planting and drainage, or indirectly by manipulation of the grazing regime, air pollution and other factors. These human activities have affected the distribution of natural species and influence the evolution of the landscape.

Strictly speaking, the term ‘natural forest’ (or forest which has not been affected by any human activity) only applies to a very few, very small remnants of forested land. Nevertheless, the term is often used. The official definition of natural forest used in Denmark provides a good, broad explanation of the term. Natural forest originates from the original forest cover, i.e. a forest reproduced naturally. Natural forest is thus a forest which has spontaneously generated itself on the location and which consists of naturally immigrant tree species. Natural forests can be more or less influenced by culture, e.g. by logging or regeneration techniques, but the forests must not have been subject to regeneration by sowing or planting".

#### Frontier forests

In a 1997 study, the World Resources Institute (WRI) coined the term "frontier forests" to describe forested areas that are relatively undisturbed by human activity and are large enough to maintain their biodiversity, including viable populations of wide-ranging species. According to WRI frontier forests constitute about 40% of total forest area.   
It is interesting to note that contrary to popular belief, many areas that might appear to be undisturbed forest are not in fact ‘pristine’ or ‘frontier’ forest. Ecological, historical, and archaeological studies have shown, for example, that even the Amazon forest has been inhabited, utilized and disturbed in many ways by humans for millennia.

#### The 'pristine' Amazon forest

Although the Amazon forest is commonly believed to be one of the earth’s largest expanses of untouched, ‘virgin’ forest, there is a growing consensus among ecologists, historians, and archaeologists that there are few parts of the region which have never been subject to human influence. Indeed, there is strong evidence now that the region has a long history of settlement and that over time, these settlements have modified the forest ecosystems. Researchers in the Amazon have found unusual concentrations of plants used by humans, suggesting quite high human population densities in the past. Estimates of the human population at the time of the European conquests around 1500 range from 1 to 6 million (sometimes higher). The region’s population has only recently returned to these levels with the notable difference that nowadays they mostly live in towns and cities rather than farming in the forest. This population used to raise crops in managed fallows. The amount of cleared area in 1500 was probably close to that prevailing in 1990. Forest fires were probably as common as at present, but on a smaller scale. Overall these populations have significantly altered plant and animal distribution and densities. The notion of an undisturbed wild Amazonian forest is an artifact.

**Functional classification of forests**

(A) Protection forests:

Physical, climatic considerations

(B) National forests:

Defense, communications, industry,

(C) Village forest:

fuel wood, small timber, grazing to meet local requirement

(D) Tree lands:

outside the scope of ordinary forest management for amelioration of physical condition of country

**1. Protection forest**

* On hill slope, river banks, sea shore or other erodible areas
* Aims is to protect forests for physical consideration
  + prevention of erosion, soil conservation
  + flood prevention
  + maintain stream flow
* Production and harvest of timber within safety limits
* focus on hillside protection, river bank treatments, desert stabilization,

**2. National Forests**

* Comprise valuable timber bearing regions
* Produce needed for defense, communications, and industries
* To be managed in national interests on scientific and business lines
  + sustained supply of timber
  + cultivation not to be permitted

**3. Village Forests**

* Mainly for fuel wood purpose to meet local needs of agricultural implements, small timber, fuel wood, fodder etc
* Supply at concessional rates for self use
* Management in perpetuity
  + Harvest less than increment
  + Entrust management to village *panchayats*
  + Profit motive subordinate to local requirements
  + But expenses for the management of such forests should come from local people

**4. Tree lands**

* Tree planting for meeting local needs and climate amelioration
* Large scale plantation needed- 2000 crore trees needed for maintaining hydrological balance
* SFD alone cannot do it
* Make country tree conscious
* Encourage private tree planting
* Popularise Van Mahotsava
* Increase tree land involving government agencies like Defense, Railways, PWD, Universities, local bodies etc

The duty of the Forest Departments for increasing tree lands:-

* Awaken interest of authorities in establishment of tree  lands
* Plan for planting keeping in view species of commercial importance
* To establish nurseries and seed stores
* To supervise the planting  of trees, provide technical assistance
* Increase tree awareness among the people by publicity,   *Vana* M*ahotsava,*    Van premi Sangh

**Proportion of forest areas**

Maintaining one-third of its total land area under forests. 60 % forests in the Himalayas, the Deccan, and other mountainous ,20% forests-In the plains.

**Wild Life:**

A Central Board for Wild life has been constituted by the Government of India in the Ministry of Food and Agriculture at 4th April, 1952.

**Grazing:**

Grazing should be regulated. Continuous grazing in the same area should controlled. Grazing rate should be kept at a minimum in 'Protection Forests'.

**Cooperation with industry:**

* + Contact between the Forest department and industries
  + Utilization of the results of research in industrial benefit.

**Forest budgets:**

Forestry is a long range enterprise , Income from supply of large timber for defense and industry , Supply of large-sized timber is greater importance to the general economy of the country, Immediate Profit motive to be ruled out ,Provision of sinking fund.

**Questionnaires**

1. Write down the classification of forest on the basis of age, regeneration, composition, legal status and growing stock.
2. Define silvics and silviculture. What are the objective of silviculture?
3. What are the major types of forest in the world?
4. Describe the functional classification of forest?

**Chapter 3**

Objectives of forest polices

The purpose of a society in establishing policies about what its members do is to try to assure that their actions will contribute as much as possible toward some ends which the society deems desirable.

A policy is this means to some end and its effectiveness on only budged in form of those ends. However many of the ends towards which policies are aimed are desirable only because they in turn become means towards the achievement of other ends. When guidelines or principles to protect and conserve provides any legal framework to protect the forest so that every individual is enforced to follow failing which there will be legal action, it will be called as forest law. Forest policies are 1. Forest policy 1894, 2. National Forest Policy 1952 and 3. National Forest Policy 1988. The forest laws are 1. Indian Forest Act 1952, 2. Wildlife Protection Act 1972, and 3. Forest Conservation Act, 1980.

A society may have on objective of adequate wood supplies for all consumer needs. It is therefore establishes a policy of increasing the growth of timber in its forest on one way which will reduce the occurrence and severity of wild forest fire though it will lead to destroying bio diversity and ethical values from the forests. A second objective thus arises of keeping forest fire damage to a minimum.

The most obvious objective of any society with forest for formulation of policy is as below:

* It is to obtain the benefits from forests. These potential benefits cover a wide range including wood products, other vegetative products, animal products, water, recreation sites, flood reduction, soil stabilization, modification of climatic conditions, and environmental amenity. Not all forests are potentially capable of producing all the benefits.
* setting aside the forest reserves and in developing public forestry programs to ensure a future supply of wood, fodder, fuel.
* The concepts of Biodiversity, ecological balance, environmental stability have been receiving much more attention in recent years with growing concentration of population in urban areas. The most fundamental objective of my society is probably survival which may be ensured through viable policy.
* Economic development is ensured by the policy which is back bone of survival. Forests may occupy an important place in the development of countries by contributing to GDP (1-2%) besides contributing livelihood of quarter of population directly or indirectly.
* In order to obtain the benefits of wood products, one must at the trees and remove usable portion from the forest. in this process one will make drastic changes in the vegetative cover on the area and perhaps also in soil conditions by proper management tools.
* The magnitude of the adverse effects may be controlled of some extent, and this is through working plan and sustainable forest management.
* Multiple use of course is not the rational objective of forest policy. A sound policy being able to provide maximum of yield of every components this will provide the potential forest benefits.
* Security and national welfare besides health and welfare of the people is another fundamental objective of forest policy. Since a well stock forest provides the best outdoor recreation which is conducive to health besides the favorable environment which are ensured for health and welfare which will be ensured by policy.
* Economic development is an objective which has received a great attention in recent years. Forests may occupy an important place in the development of countries and revolution of industries which are indispensable to growing civilization and ensured in long run.

**NATIONAL FOREST POLICY - 1894**

 Introduction

No. 13-1/52-F-In their Resolution No. 22-F., dated the 19th October, 1894, the Government of India in the late Department of Revenue and Agriculture enunciated in broad outlines the general policy to be followed in the management of State forests in the country. The features of the policy are:

* The part played by forests in maintaining the physical conditions in the country has come to be better understood. The country has passed through two world wars which disclosed unsuspected dependence of defence on forests. The reconstruction schemes, such as river-valley projects, development of indus­tries and communications, lean heavily on the produce of forests.
* Government of India, consider that the need hag. now arisen for a re-orientation of the forest policy in the light of the changes which ,have taken place since it was enunciated.
* Vital national needs-The National Forest Policy of India is formulated on the basis of six

paramount needs of the country, namely:-

(1) the ,need for evolving a system of balanc­ed and complementary land-use, under which each type of land is allotted to \_hat, form of use. under which it would  produce most and deteriorate least;

(2) the need for checking-

(a) denudation in mountainous regions, on which depends the perennial water supply of the river system whose basins constitute the fertile core ofthe     country;

 (b) the erosion progressing space along -the 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 on coastal tracts, and the shifting of sand dunes, more   particularly in the Rajputana desert; .

(3) the need for establishing treelands, wherever possible, for the amelioration of physical and climatic conditions promoting the general well being of the people;

(4) the need for ensuring 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  defence, communications and industry;

(6.) the need for the realisation of the maxi­mum annual revenue in perpetuity consistent with the fulfilment of the needs enumerated above.

These vital needs indicate the functions forests are to fulfil, and 'provide the fundamental basis of the policy governing their future.

* Functional classification of forests-Having regard to the functions afore-stated, the forests of India, whether State or privately owned, may be 'conveniently Classified as follows:-

(A) *Protection forests,* i.e., those forests which must be preserved or created for physical and climatic considerations;

(B) *National forests,.* i.e., those which have to be maintained and managed to meet the   needs of defence, communications, indus­try, and other general purposes of public importance;

(C) *Village forests,* i.e., those which have to be -maintained to provide firewood to re­lease cow-dung for manure, and to yield small timber for agricultural implements and other forest produce for local re­quirements, and to provide grazing for cattle;

(D)*Tree-lands,* i.e., those areas which though outside the scope of the ordinary forest management are essential for the amelio­ration of the physical conditions of the country.

**FOREST POLICY, 1952**

**State, Communities and Forest Policy**

* State as sole arbiter of forest estate
  + Forest Act, 1927
  + Forest Department as custodian
  + Focus on consolidation of estate [ Abolition of princely estates]
  + Claims of nation building on forests, revenue generation for growth
  + Nehruvian vision of Development
* Communities
  + Predominantly agrarian, dependent on forests
  + Differential bargaining power vis-à-vis industry
* Forest Policy
  + Reflect socio-economic context [ Nation Building]
  + Accommodation of conflicting claims and objectives
  + Industrial forestry to get precedence
  + Give direction to forestry sector

The First Forest Policy of 1894 was revised in 1952 on the basis of six paramount needs of the country

* 1. The need for balanced and complementary land-use
     + Most productive land use
  2. The need for checking of soil erosion
     + Treat catchments areas for soil and water conservation
  3. Establishing tree lands
     + Amelioration of physical and climatic conditions
  4. Ensuring increasing supplies of grazing, small wood for agricultural implements, fuelwood
  5. sustained supply of timber - defense, communications and industry.
  6. Maximum annual revenue in perpetuity.

**NATIONAL FOREST POLICY, 1988**

In Resolution No.13/52/F, dated the 12th May, 1952, the Government of India in the erstwhile Ministry of Food and Agriculture enunciated a Forest Policy to be followed in the management of State Forests in the country. However, over the years, forests in the country have suffered serious depletion. This is attributable to relentless pressures arising from ever-increasing demand for fuel-wood, fodder and timber; inadequacy of protection measures; diversion of forest lands to non-forest uses without ensuring compensatory afforestation and essential environmental safeguards; and the tendency to look upon forests as revenue earning resource. The need to review the situation and to evolve, for the future, a new strategy of forest conservation has become imperative. Conservation includes preservation, maintenance, sustainable utilization, restoration, and enhancement of the natural environment. It has thus become necessary to review and revise the National Forest Policy.

The basic objectives

* 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.
* 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.
* Checking soil erosion and denudation in the catchment areas of rivers, lakes, reservoirs in the "interest of soil and water conservation, for mitigating floods and droughts and for the retardation of siltation of reservoirs.
* Checking the extension of sand-dunes in the desert areas of Rajasthan and along the coastal tracts.
* Increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands.
* Meeting the requirements of fuel-wood, fodder, minor forest produce and small timber of the rural and tribal populations.
* Increasing the productivity of forests to meet essential national needs.
* Encouraging efficient utilization of forest produce and maximizing substitution of wood.
* Creating a massive people's movement with the involvement of women, for achieving these objectives and to minimize pressure on existing forests.

The principal aim of Forest Policy must be to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which are vital for sustenance of all life forms, human, animal and plant. The derivation of direct economic benefit must be subordinated to this principal aim.

**WILD LIFE (PROTECTION) ACT 1972**

The Government of India enacted ***Wild Life (Protection) Act 1972*** with the objective of effectively protecting the wild life of this country to control poaching, smuggling and illegal trade in wildlife and its derivatives. The Act was amended in January 2003 and punishment and penalty for offences under the Act have been made more stringent. The Ministry has proposed further amendments in the law by introducing more rigid measures to strengthen the Act. The objective is to provide protection to the listed endangered flora and fauna and ecologically important protected areas.

Chapter-1

1. This Act may be called the Wildlife (Protection) Act, 1972.
2. It extends to the whole of India, except the State of Jammu and Kashmir.\*]

It shall come into force in a State or Union Territory to which it extends, on such date as the Central Government may, by notification, appoint, and different dates may be appointed for different provision of this Act or for different States or Union Territories.

Chapter -2

Appointment of Director another officers.

Appointment of Chief Wildlife Warden and other officers

**Constitution of the Wildlife Advisory Board.–**

1. The State Government, or, in the caseof a Union Territory, the Administrator, shall, as soon as may be after the commencement of this Act, constitute a Wildlife Advisory Board consisting of the following member, namely:
   1. the Minister in charge of Forest in the State or Union Territory, or, if there is no such Minister, the Chief Secretary to the State Government, or, as the case may be, the Chief Secretary to the Government or the Union Territory, who shall be the Chairman;
   2. two members of the State Legislature or, in the case of a Union Territory havinga Legislature, two members of the legislature of the Union Territory, as the case may be;
   3. Secretary to the State Government, or the Government of the Union Territory, in charges of Forests;

[(d) The Forest Officer in charge of the State Forest Department, by whatever designation called, ex-officio; 4 ]

1. an officer to be nominated by the Director;
2. Chief Wildlife Warden, ex-officio;
3. Officers of the State Forest Government not exceeding five5 ];
4. such person, not exceeding ten, who, in the opinion of the State Government are interested in the protection of Wildlife, including the representatives of tribals not exceeding three. (1A) The State Government may appoint a Vice-Chairman of the Board from amongst the members referred to in clauses (b) and (h) of sub-section (1). 6] (2) The State Government shall appoint [the forest Officer incharge of the Forest Department 7 ] or Chief Wildlife Warden as the Secretary to the Board.

**Procedure to be followed by the Board** –

1. The Board shall meet at least twice a year at such place as the State Government may direct.
2. The Board shall regulate its own procedure (including the quorum).
3. No act or proceeding of the Board shall be invalid merely by reason of the existence of any vacancy therein or any defect in the constitution thereof or any irregularity in the procedure of the Board affecting the merits of the case.

**Duties of the Wildlife Advisory Board** – It shall be the duty of the Wildlife Advisory Board to advise the State Government,–

* 1. In the selection of areas to be declared as Sanctuaries, National Parks, and Closed Areas and the administration thereof ;
  2. in formulation of the policy of protection and conservation of Wildlife and specified plants;
  3. in any matter relating to any schedule; (cc) in relation to the measures to be taken for harmonizing the needs of the tribals and other dwellers of the forest with the protection and conservation of wildlife;

Chapter- IIA

**Hunting of Wild Animals**

1. Prohibition of Hunting
2. Maintenance of records of wild animals killed or captured
3. Hunting of wild animals to be permitted in certain cases
4. Grant of permit for special purposes
5. Suspension or cancellation of licence
6. Appeals
7. Hunting of young and female of wild animals
8. Declaration of closed time

Restrictions on hunting

Chapter**-** IIIA

17A Prohibition of picking, uprooting. etc., of specified plants

17B Grant of permit for special purposes

17C Cultivation of specified plants without licence prohibited 17D Dealing in specified plants without license prohibited 17E Declaration of stock

17F Possession, etc., of plants by licensee 17G Purchase etc., of specified plants 17H Plants to be Government property

17A. Prohibition of picking, uprooting, etc., of specified plants

1. willfully pick, uproot, damage destroy, acquire or collect any specified plant from any forest land and area specified, by notification, by the Central Government,
2. possess, sell, other for sale, or transfer by way of gift or otherwise, or transport any specified plant, whether alive or dead, or part or derivative thereof
3. Provided that nothing in this section shall prevent a member of a scheduled tribe, subject to the provisions of Chapter IV, from picking, collecting or possessing in the district he resides any specified plant or part or derivative thereof for his bonafide personal use.

17B. Grant of permit for special purpose-

The Chief Wild Life Warden may with the previous permission of the State Government, grant to any person a permit to pick, uproot, acquire or collect from a forest land or the area specified under section 17A or transport, subject to such conditions as may be specified therein, any specified plant for the purpose of ) education; (b) scientific research., (c) collection, preservation and display in a herbarium of any scientific institutions; or (d) propagation by a person or an institution approved by the Central Government in this regard.

17C. Cultivation of specified plants without licence prohibited-

(1) No person shall cultivate a specified plant except under, and in accordance with a licence granted by the Chief Wild Life Warden or any other officer authorised by the State Government in this behalf

Every licence granted under this section shall specify the area in which and the conditions, if any, subject to which the licensee shall cultivate a specified plan

17D. Dealing in specified plants without licence prohibited.–

(1) No person shall, except under and in accordance with a licence granted by the Chief Wild Life Warden or any other officer authorized by the State Government in this behalf, commence or carry on business or occupation as a dealer in a specified plant or part or derivative

17E. Declaration of stock.– (1) Every person cultivating, or dealing in, a specified plant or part or derivative thereof shall, within thirty days, from the date of commencement of the Wild Life (Protection) Amendment Act, 1991, declare to the Chief Wild Warden or any other officer authorized by the State Government in this behalf, his stocks of such plants and part or derivative thereof, as the case may be, on the date of such commencement.

17G. Purchase, etc., of specified plants.–

17H. Plants to be Government property. –

[Chapter-](http://www.moef.nic.in/legis/wildlife/wildlife1c4.html) IV

**Sanctuaries, National Parks and Closed Areas**

**Sanctuaries**

1. Declaration of Sanctuary
2. Collector to determine rights
3. Proclamation by Collector
4. Inquiry by Collector
5. Powers of Collector
6. Acquisition of rights
7. Delegation of Collector's powers 26A Declaration of area as Sanctuary
8. Restriction on entry in sanctuary
9. Grant of permit
10. Destruction, etc., in a sanctuary prohibited without a permit
11. Causing fire prohibited
12. Prohibition of entry into sanctuary with weapon
13. Ban on use of injurious substances
14. Control of sanctuaries

33A Immunization of live stock

[Chapter IVA](http://www.moef.nic.in/legis/wildlife/wildlife1c4a.html)

**Central Zoo Authority and Recognition of Zoos**

Chapter [V](http://www.moef.nic.in/legis/wildlife/wildlife1c5.html)

**Trade or Commerce in Wild Animals, Animal Articles and Trophies**

Chapter [VI](http://www.moef.nic.in/legis/wildlife/wildlife1c6.html)

**Prevention and detection of offences**

1. Power of entry, search, arrest and detention
2. Penalties
3. Attempts and abetment
4. Punishment for wrongful seizure
5. Power to compound offences
6. Cognizance of offences
7. Operation of other laws not barred
8. Presumption to be made in certain cases
9. Offences by companies

Chapter VII

**Miscellaneous 59.**

1. Officers to be public servants
2. Protection of action taken in good faith
3. Power to alter entries in schedules. – (41) The Central Government may, if it is of the opinion that it is expedient so to do, by notification, [4 add or delete any entry to or from any schedule] or transfer any entry from one part of the schedule to another part of the same schedule or from one schedule to another
4. Declaration of certain wild animal to be vermin. - [8 The Central Government] may by notification, declare any wild animal other than those specified in Sch. I and part 11 of Sch H to be vermin for any area and for such period as may be specified therein and so long as such notification is in force, such wild animal shall be deemed to have been included in Sch.V.

65. Rights of Scheduled Tribes to be protected. - Nothing in this Act shall affect the hunting rights conferred on the Scheduled Tribes of the Nicobar Islands in the Union Territory of Andaman and Nicobar Islands.

**Questionnaires:**

1. Describe the Forest policy 1952 ?
2. In which year wildlife protection act is enacted in India ?
3. In which year elephant conservation act is enacted in India?

**Chapter 4**

Forest regeneration is the process by which new tree seedlings become established after forest trees have been harvested or have died from fire, insects, or disease. Regeneration is key to sustainable forestry and can be accomplished through two basic approaches:

* Natural regeneration, which occurs when new seedlings or sprouts are produced by trees left on or near the site (as with aspen)
* Artificial regeneration, more commonly known as tree planting

**Methods of Regeneration**

There are basically two methods of regeneration of forests A. Natural regeneration B. Artificial regeneration

The choice of the method of regeneration depends on

* 1. **Land owners objectives:** It depends on the viability of the required capital manpower, machineries, planting materials and the technology of regeneration with the land owner
  2. **Site and stand characteristics:** If the stand is well and good and in its climax stage of growth then the natural regeneration is followed. However, in case of damaged stand with sparse population the artificial method of regeneration is to be practiced.
  3. **Purpose or future prospects of the regenerated forest use**: If the cash flow expected is quite assured then it is wise and good to go for the artificial regeneration.
  4. **Depending on the nativity of the species**: If the plant is exotic one and is introduced to a new area where it has not been there and thus requires special care and attention then the artificial method should be followed.

**Advantages of natural regeneration method:**

1. Low establishment cost

2. Relatively less labour and heavy machineries available

3. Little soil disturbances

4. No problem with the geographical origin of the seed

5. Independent of nursery grown seedlings

6. Lesser disease and pest problem

**Disadvantages of natural regeneration methods:**

1. Little control over spacing and initial stocking density
2. Cannot use genetically improved varieties
3. Loss of income due to leaving seed trees
4. Stand regeneration may get delayed due to inadequate seed crops
5. Produce irregular stand unsuitable for mechanical harvesting
6. Does not permit species conversion

**Advantages of the artificial regeneration:**

1. Good control over spacing and initial stocking density
2. Can use genetically improved planting stocks
3. Independent of natural seed crops
4. Permits species conversion
5. Few entries into stand needed to prepare for regeneration

**Disadvantages of Artificial regeneration:**

1. High establishment costs.
2. Intensive labour and equipment use
3. Severe insect and disease problem with some species

## Natural regeneration

Natural regeneration is defined as the renewal of a forest crop by self-sown seed or by coppice of root suckers. To regenerate means ‘to renew a forest crop by natural or artificial means’. Thus, regeneration (syn. Reproduction) is defined as ‘the renewal of a forest crop by natural or artificial means.

**Importance**

* Species always are well adapted to the localities
* Multi-purposes species are grown naturally
* Better conservation of biodiversities and amelioration of ecosystems
* Meeting requirements of people and their domestic animals
* Better wildlife habitats
* More suited to conservation of soil and improvement of watersheds
* Seedlings found have already be naturally hardened-off
* Injurious or damaging species are found suppressed by natural pests or plants
* Nursery grown seedlings are not necessary
* Low cost and more net financial returns
* Special Supervision of any kinds are not necessary
* Vigorous growth of trees of favored species

## Factors affecting natural regeneration

Factors affecting natural regeneration are given as follows:

1. Climatic Factors
   * Solar Radiation and Light
   * Precipitation
   * Local Temperature
   * Humidity (Atmospheric Moisture)
   * Frost
   * Snow Fall
   * Evapo-transpiration
2. Soil Factors
   * Organic matter and nutrient status
   * Soil structure and texture
   * Soil Temperature
   * Chemical Properties of Soil
   * Biological Properties of Soil
   * Erosion and Floods
3. Biological Factors
   * Man and his activities
   * Wild life and domestic animals
   * Diseases and Pests
   * Heavy growth of grasses and weeds
   * Forest fires

## Methods of natural regeneration

### A. Natural regeneration (NR) from seed

When regeneration obtained from seed forms a crop, it is called a seedling crop. It is neither planted nor of coppice or root-sucker origin but originating in situ from natural regeneration. When this seedling crop grows into a forest, it is called a high forest.

NR from seed depends on the followings:

1. **Seed Production:** The most important consideration for natural regeneration from seed is the production of adequate amount of fertile seeds by the trees of the area or in the vicinity. The production of seed depends on the following: species, age of trees, size of crown, climate, and other external factors.
2. **Seed Dispersal:**The seed produced by the trees is dispersed by the agency of wind, water, gravity, birds and animals.

Some examples of seed dispersal by various agencies are given below:

* Wind: Conifers, Acer, Betula, Populus, Alnus , Salix, Terminalia, Dalbergia, Acacia , Adina , Bombax, etc.
* Water: Most mangrove species, Dalbergia, Teak, etc.
* Birds: Prunus, Mulberry, Diospyrus, etc.
* Animals: Acaica arabica, Prosopssis juliflora, Zizyphus, Anthocephallus, etc.
* Gravity: Oak, Juglans, Asculus, etc.

1. **Seed Germination:** After dispersal, insects, birds and rodents destroy a lot of seeds. The others germinate provided they are deposited on suitable soil.

Germination of seeds depends upon several internal and external factors listed below:

* Internal Factors: Permeability to water, permeability to O2, development of embryo (i.e., Fraxinus floribunda takes one year), after ripening (i.e., Juniperus macropoda), viability of seeds, size of seeds, germination capacity, germination energy
* External factors: Moisture, air, temperature, light (i.e., Cassia fistula or Albizzia procera requires light), seed Bed.

1. **Seedling Establishment:**Even if germination is good, it does not mean that natural regeneration would be good because a large number of seedlings die at the end of rains or as a result of frost during winter or drought during summer. In addition, there may be other factors such as weeds, grazing, fire, which may kill the seedlings. Thus, establishment is defined as the development of new crop ‘naturally or assisted’ to a stage when the young regeneration ‘natural or artificial’ is considered safe from normal adverse influences and no longer needs special protection or tending operation other than cleaning, thinning and pruning.

The following factors affect establishment of seedlings:

* + Development of roots
  + Soil conditions – Moisture, Aeration, Nutrients
  + Light
  + Other Climatic Factors- high or low temp.
  + Rainfall
  + Drip (Slash erosion)
  + Condition of grasses and other competing weeds
  + Grazing, Browsing and Fire
  + Composition of the crop

### Chapter 5

### Natural regeneration from vegetative parts

When regeneration obtained by coppice forms a crop, it is called coppice crop and when it develops into a forest, it is called coppice forest to differentiate it from the high forest (from seeds).

Vegetative reproduction can be obtained by any of the following methods:

1. **Coppice:** Vegetative reproduction in which the tree, plants or the seedlings of a species when cut near the ground level produce shoots.
2. **Root Sucker** (A shoot rising from the root of a woody plant): Vegetative reproduction in which a root of a plant is partially or wholly cut to produce a shoot called root sucker.
3. **Cutting:** Vegetative propagation in which a portion of the stem, branch or root is placed in the soil or other medium, in order that it may develop into a plant. Depending on the part of the plant used, cuttings may be classified into stem cutting, branch cutting, root cutting and root and shoot cutting. Root and shoot cutting is a young plant with pruned taproot and severed stem used for planting.
4. **Layering:** Inducing development of roots on branches while they are still attached to the trees is called layering. Layering may be done in soil or in air and so layering is of two kinds: air Layering and soil Layering
5. **Grafting:** Vegetative propagation in which a portion called scion (any unrooted portion of a plant used for grafting or budding on a rooted stock), of one plant is applied to stock (a rooted plant on which a scion is grafted), usually rooted, which is another plant, with the object of securing vegetative union between the two, when the scion is detached from the parent plant and the shoot of the other plant is severed, to produce a new plant to be planted out. Attempt is made to transport the scions to the grafting place within 24 hours.
6. **Budding:** A vegetative reproduction in which, a bud with some portion of the bark of a genetically superior plant is grafted on an inferior plant so that it can produce shoot when the old shoot of the stock is cut off. Bud is grafted on the stock in the form of a patch after removing the bark of the stock in that portion or by making an incision in the bark of the stock in the form of T and then fixing the scion inside it.

**Coppicing**

Coppicing is a traditional method of woodland management which takes advantage of the fact that many trees make new growth from the stump or roots if cut down. In a coppiced wood, which is called a copse, young tree stems are repeatedly cut down to near ground level. In subsequent growth years, many new shoots will emerge, and, after a number of years the coppiced tree, or *stool*, is ready to be harvested, and the cycle begins again. Pollarding is a similar process carried out at a higher level on the tree. Natural regeneration by coppice can be obtained either by:

1. **Seedling coppice:** Coppice shoots arising from the base of seedlings that have been cut or burnt back. This method of obtaining natural regeneration is used for cutting back woody shoots and established reproduction which is not making any progress so that they may produce vigorous shoots and soon develop into saplings.
2. **Stool coppice:** Coppice arising from the stool or a living stump of a tree is called stool coppice. In this method, regeneration is obtained from the shoots arising from the adventitious buds of the stump of felled trees. The coppice shoots generally arise either from near the base of the stump or from its top. The shoots arising from near the top of the stump are liable to be damaged by the rotting of the upper portion of the stump as well as by wind, etc.

**Factors affecting natural regeneration by coppice:**

1. Species- coppicing power
2. Age of tree-pole and young trees
3. Season of coppicing- before spring
4. Height of stump-15 to 25 cm.
5. Rotation-short
6. Silvicultural system- clear felling

**Regeneration from coppice**

Coppice is that method of reproduction in which the tree, plants or, the seedlings of a species when cut from near the ground level, produce coppice shoots. Coppice shoot is defined as ‘a shoot arising from an adventitious bud at the base of a woody plant that has been cut near the ground or brut back’. Natural regeneration by coppice can be obtained either by: (1) Seedling coppice; or (2) Stool coppice

## Practice

The shoots (or *suckers*) may be used either in their young state for interweaving in wattle fencing (as is the practice with coppiced willows and hazel) or the new shoots may be allowed to grow into large poles, as was often the custom with trees such as oaks or ashes. This creates long, straight poles which do not have the bends and forks of naturally grown trees. Coppicing may be practiced to encourage specific growth patterns, as with cinnamon trees which are grown for their bark.

Another, more complicated system is called compound coppice. Here some of the standards would be left, some harvested. Some of the coppice would be allowed to grow into new standards and some regenerated coppice would be there. Thus there would be 3 age classes.

Coppiced hardwoods were used extensively in carriage and shipbuilding, and they are still sometimes grown for making wooden buildings and furniture.

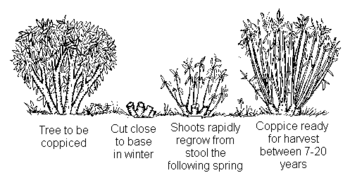


Diagram illustrating the coppicing cycle over a 7- to 20-year period

The Sal tree is coppiced in India, and the *Moringa oleifera* tree is coppiced in many countries, including India.

Sometimes former coppice is converted to high-forest woodland by the practice of singling. All but one of the regrowing stems are cut, leaving the remaining one to grow as if it were a maiden (uncut) tree.

The boundaries of coppice coups were sometimes marked by cutting certain trees as pollards or stubs.

## Natural coppicing

Coppice and pollard growth is a response of the tree to damage, and such damage can occur naturally as well as from silviculture. Trees may be browsed or broken by large herbivorous animals, such as cattle or elephants, felled by beavers or blown over by the wind. Some trees, such as linden, may produce a line of coppice shoots from a fallen trunk, and sometimes these develop into a line of mature trees.

Artificial coppice may therefore be seen as a somewhat distorted equivalent to natural habitats which no longer occur, in the absence of now extinct or rare animals.



# Pollarding

Pollarding is a pruning system in which the upper branches of a tree are removed, promoting a dense head of foliage and branches. Pollarding in Ancient Rome was mentioned by Propertius during the 1st Century BC. It has been common in Europe since medieval times and is practiced today in urban areas worldwide, primarily to maintain trees at a predetermined height.



A line of pollarded willows in Germany.

Traditionally, trees were pollarded for one of two reasons: for fodder to feed livestock, or for wood. This is not a practice to use if one wants an attractive, natural tree as the natural growth is stunted. Older pollards often become hollow, so can be difficult to age accurately. Pollards tend to grow slowly, with narrower growth rings in the years immediately after cutting.

[](http://www.wildwillowdesign.com/2012/12/the-dos-and-donts-of-tree-pollarding/attachment/243/)As in coppicing, the tradition of pollarding is to encourage the tree to produce new growth on a regular basis to maintain a supply of new wood for various purposes, particularly for fuel. In some areas, dried leafy branches are stored as winter fodder for stock. Depending upon the use of the cut material, the length of time between cuttings will vary from one year for tree hay or withies, to five years or more for larger timber. Sometimes, only some of the re grown stems may be cut in a season – this is thought to reduce the chances of death of the tree when recutting long-neglected pollards.

## Species

Some smaller tree species do not readily form pollards, because cutting the main stem stimulates growth from the base, effectively forming a coppice stool instead. Examples of trees that do well as pollards include broadleaves such as [beeches](https://en.wikipedia.org/wiki/Beech) (*Fagus*), [oaks](https://en.wikipedia.org/wiki/Oak) (*Quercus*), [maples](https://en.wikipedia.org/wiki/Maple) (*Acer*), black locust or false acacia ([*Robinia pseudoacacia*](https://en.wikipedia.org/wiki/Robinia_pseudoacacia)), [hornbeams](https://en.wikipedia.org/wiki/Hornbeam) (*Carpinus*), lindens and limes ([*Tilia*](https://en.wikipedia.org/wiki/Tilia)), planes ([*Platanus*](https://en.wikipedia.org/wiki/Platanus)), horse chestnuts ([*Aesculus*](https://en.wikipedia.org/wiki/Aesculus)), mulberries ([*Morus*](https://en.wikipedia.org/wiki/Morus_%28plant%29)), redbud ([*Cercis canadensis*](https://en.wikipedia.org/wiki/Cercis_canadensis)), tree of heaven ([*Ailanthus altissima*](https://en.wikipedia.org/wiki/Ailanthus_altissima)), [willows](https://en.wikipedia.org/wiki/Willow) (*Salix*), and a few conifers, such as [yews](https://en.wikipedia.org/wiki/Taxus) (*Taxus*).

The technique is also used in Africa for [moringa](https://en.wikipedia.org/wiki/Moringa_oleifera) trees, to bring the nutritious leaves into easier reach for harvesting. Pollarding is also used in urban forestry in certain areas for reasons such as tree size management, safety, and health concerns. It removes rotting or diseased branches to support the overall health of the tree, living and dead branches that could harm property and people, as well as expanded foliage in spring for aesthetic, shade and pollution concerns.

Oaks, when very old, can form new trunks from the growth of pollard branches, i.e. surviving branches which have split away from the main branch naturally.

# The Do’s and Don’ts of Tree Pollarding

[](http://www.wildwillowdesign.com/2012/12/the-dos-and-donts-of-tree-pollarding/attachment/009/)[](http://www.wildwillowdesign.com/2012/12/the-dos-and-donts-of-tree-pollarding/pollarded_willow-natubes-wikimedia-commons/)Every spring numerous straight long and leafy sprouts emerge from these knobs to produce a dense, shady canopy.

**A properly pollarded tree can live a long and healthy life.** But it needs regular and appropriate maintenance.

1. The sprouts should be removed every one to two years. Pollard sprouts are weakly attached to the knob. If they are left on the tree for years and years the sprouts become thick and heavy. They become a potential hazard.
2. The sprouts should be removed all the way back to the knob. These sprouts have been left on the knob too many years and they haven’t been pruned back to the original knob consistently. In other words don’t leave little stubby branches on the knob. **Cutting all the way back to the knob makes it easier for the tree to seal off the pruning wound and assists the tree in preserving important energy resources (carbohydrates) in the knob.** This is because pollard knobs compartmentalize readily.
3. Start the pollarding process when the tree is young – two or three years old.  Ideally you will never need to cut a limb or sprout that is more than 1” in diameter.  Over a few years a small knob will develop and expand. Each year the knob will grow larger and will harbor dormant buds, carbohydrates and wound calluses.
4. [](http://www.wildwillowdesign.com/2012/12/the-dos-and-donts-of-tree-pollarding/210-2/)**Do not attempt to start the pollarding process on a mature tree that has not been pollarded before.**  This is REALLY hard on a tree. Sprouts will emerge from below the cuts and it will look sort of like pollarding. But bluntly cutting mid-node through
5. Choose trees that take well to pollarding. Sycamores, mulberries and horse chestnuts respond well.  You can find other species online by searching for “trees for pollarding”.

**Regeneration from root suckers**

Root sucker is a shoot rising from the root of a woody plant. It is that method of vegetative reproduction in which a root of a plant is partially or wholly cut to produce a shoot called root sucker. Natural regeneration by root suckers is not being attempted on any large scale anywhere in this country. This method used to be followed, sometimes, on the canal bank plantations in India and the chief species in which this was affected was sissoo. Where this method was followed, it was usual to dig continuous or discontinuous circular trenches with diameter of about 6 m round the isolated trees so that their roots may be severed and root suckers produced, which, with tending, could be developed into trees. The trees produced in this way are liable to wind-throw and poor in growth and therefore this method is not being favoured now. Diospyros root suckers are sometimes encouraged because the root suckers produce best biri.

Tree suckers are small tree sprouts that grow upward from tree root systems. Suckers have their own roots that make them a simple and fast method of propagation. The single sprouts produce a tree when removed from where they are growing and transplanted properly in a new location. Propagating suckers works best on trees that do not have a grafted root system so you know the tree sucker is the same variety as the main tree.

1. Inspect the tree and sucker growth to find suckers that are away from the main trunk for easier removal. Choose suckers that will cause the least amount of damage to the tree when removing.
2. Dig 4 to 6 inches around the sucker with a small spade carefully until you reach the main root from the tree. Clip the sucker roots with a sharp pruning clipper to remove the sucker from the tree. ensure there are roots extending from the base of the section you remove. Lift the sucker from the ground with as much soil around the roots as possible for protection.
3. Set the sucker on a clean tarp and moisten the soil and roots with water to prevent moisture loss.
4. Select a planting area with the same amount of sunlight and soil as the previous growing area. Dig a hole that is twice as wide as the sucker root mass and deep enough so the sucker is at the same depth as it was in the original planting area.
5. Set the root ball into the hole so the sucker is straight. Pack soil around the roots to hold the sucker in place. Moisten the planting area with water to compact the soil and remove air pockets that may have formed.
6. Apply water three times a week to keep the soil moist during the first month after planting when rain isn't present to assist with root.

**Chapter 6**

**Artificial regeneration and its importance**

The renewal of a forest crop by sowing, planting or other artificial methods. It also refers to the crop so obtained. It is also called plantation in another term, which is defined as ‘ a forest crop raised artificially, either by sowing or planting.’ A term wilding which is defined as ‘ a natural seedling used in forest planting.

**Objectives of artificial Regeneration**:

A) Reforestation, and B) Afforestation

Objectives of reforestation:

1. To supplement natural regeneration

2. To give up natural regeneration in favor of artificial regeneration

3. To restock forests destroyed by fire and other biotic factors

4. To change the crop composition

5. To introduce exotic.

Objectives of manmade/plantation forest:

1. Increase the yield from forest to meet the fast increasing demand of timber for building construction, industries, defense and communications.

2. Shorten the rotation by raising fast growing species.

3. Locating forests with relation to the location of industries.

4. Meeting the demand of agricultural implements, hosing, fodder and firewood of the rural population. 5. Improvement of agro-ecosystem, control of erosion and beautification of countryside.

6. Concentration of work resulting in easier supervision, easier mechanization of operation, cheaper logging and extraction.

7. Increasing employment potential.

**Essential preliminary consideration:**

After deciding in favor of artificial regeneration, decision has to be taken on the following essential preliminary considerations;

I. Choice of species: - depends on the following factors. a) Climate and micro-climate b) Soil condition Stiff kankar clay• Lime rich soil • Soils with soluble salt• Clayey soil • c) Stage of succession d) Objective of management e) Consumer's requirement f) Growth rate g) Availability of suitable exotic h) Ease of establishment i) Cost j) Effect on site Mixture in plantation: In order to decide (pure or mixed),

Merits and demerits of pure and mixed crops may be assessed from the point of view of following considerations:- 1. Soil deterioration 2. Resistance to diseases 3. Damaged by wild animals 4. Increment of total yield 5. Difficulty in execution of silvicultural operations as well as management.

Kinds of Mixture: A) Temporary mixture: For following objectives

a) Providing protection against adverse factors. b) Providing competition in the early stage to obtain better bole form. c) Providing additional revenue. d) Providing covers to the ground and suppression of weeds. B) Permanent mixture: In which the mixed species remains with main species throughout the rotation of the crop.

Objective: - to avoid risk to which pure crops are exposed. Kinds of Permanent mixture: a) Horizontal or even aged mixture b) Vertical or uneven aged mixture or storeyed mixture. Pattern of mixture: a) Intimate mixture b) Line mixture c) Strip mixture d) Block mixture II. Selection of site III. Choice of methods of artificial regeneration a) Direct seed sowing or b) Seedling planting Advantages of sowing Disadvantages of sowing Advantages of planting Disadvantages of planting

The species to be raised•The choice between the two methods (sowing or planting) of artificial regeneration depends upon; Availability of seed• Condition of site • Cost• Spacing: - Spacing varies with species and the local conditions. The following factors govern the spacing; a) Rate of growth of species: - Fast growing species have wider spacing and slow growing species have closer spacing. b) Habit of branching: - large number of branches reduce the volume and value of timbers so, plant in close spacing. c) Number of annual rings per centimeter: - this type of denser wood species wider spacing. d) Height of planting material: - If tall plants are to be used for planting, the spacing should be wider, if small planting stock is to be planted spacing should be closer. e) Site factor: - In dry area, spacing should be closer. Inter cultivation: - wider spacing for tractor ploughing and cultivation of agricultural crops, as a intercropping tree with agro-forestry crops. g) Market for small sized timber: - The crop raised in closer spacing. h) Fruit production as objective: - Spacing should be wider depends on fruit bearing species. i) Cost: - Close spacing requires much cost than wider spacing. Therefore availability of funds has a great influence on the spacing to be adopted.

1.2 Methods of Artificial Regeneration: Artificial regeneration can be done either by sowing of seed directly in plantation area or by planting seedlings or cuttings obtained from some nursery. Methods of Artificial Regeneration: Artificial regeneration can be done either by sowing of seed directly in plantation area or by planting seedlings or cuttings obtained from some nursery.

**Regeneration from seed**

Kinds of Sowing: sowing may be done in any of the following ways: a) Broad-cast Sowing: It is the process of scattering of seed over the whole area, either that on which the crop is to be raised directly or a nursery bed. It is generally recommended for stocking burnt areas, abandoned cultivation, landslides and grassy blanks. b) Line Sowing: In this method, sowing of seed is done in drills or single lines. Drills or lines are made at pre-determined intervals after digging soil in those places. It may be continuous line sowing when drill is made from one end of plantation to other end while it may also be uninterrupted line sowing in which the area consists of dug up and sown portion alternating with undug and unsown portion. If the sown portion of line is opposite to unsown portion of adjacent lines it is called interrupted and staggered line sowing. c) Strip Sowing: In this method, seed is sown in narrow strip prepared usually at definite intervals from one another and are generally 45cm to 90cm or even 120cm wide. Like line sowing strip sowing may be continuous, interrupted and staggered. Line and Strip sowing are done either on ridges or in trenches, depending on rainfall. In high rainfall, moist and areas liable to water logging sowing is done on ridges (10 to 20cm higher than ground level) and such sowing is called ridge sowing where as in dry and low rainfall areas, the seed is sown in trench and called trench sowing. In areas with uncertain rainfall ridge ditch sowing is done in which earth is filled back in trench in sloping manner leaving part of trench unfilled. In case of poor rainfall, lowest row sowing will be successful, in case of moderate rainfall; the middle row will be successful while in heavy rainfall ridge sowing will be successful.

**Factors affecting the choice between natural and artificial regeneration**

Site Selection

When planning reforestation activities it is important to know what you have to work with. Knowledge of the soil and topography will aid in species selection, site preparation, fertilization and other management decisions. Your site may also possess features such as wetlands, riparian management zones, or the presence of endangered species which may limit or alter your management activities. A list of endangered and threatened species can be obtained from the DNR Bureau of Endangered Resources. 1. Site Characteristics **-**When choosing or evaluating a site for artificial regeneration there are several things about the site to consider.

They include the following:

a. Climate: total precipitation, drought, frost timing, insolation, ice storms, and snow loads.

b. Soil: parent material, texture, depth, rock content, compaction, frost heaving, organic matter, available moisture, nutrients, erosion patterns and internal drainage.

c. Topography: elevation, slope, aspect, surface drainage of moisture and air.

d. Institutional environment: access, labor, equipment, seed or seedling availability, federal and state cost-share incentives (eg. stewardship), taxes, regulations and constraints.

e. Existing vegetation: seeds and advanced regeneration, competition (allelopathy) and endangered resources. Animals: domestic, wild - rodents (rabbits, voles, mice), ungulates, endangered species. g. Insects: previous history, current population trends.

h. Disease: site history, vulnerability to future infection and presence of alternate host plants.

i. Productivity: productive history and overall site quality

j. Landscape: surrounding cover types in the broad geographic area, location of site in broader landscape picture and management trends.

k. Succession: trends and probable future species composition on the site.

**Site Preparation for Regeneration of Forest**

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

1)To get rid-off logging slash or other debris  
2)Reducing competition and animal habitat  
3)To prepare a mineral soil seedbed  
4)To improve drainage of surface and upper soil horizons and reduce the compaction  
5)To create a more favorable micro site on harsh sites  
6) To take measure to control disease.

**Site Preparation Methods:**Following four methods of the site preparation are commonly used all over the world:

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

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

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

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

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

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

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

**Questionnaires:**

1. Explain the natural regeneration from seed and the factors affecting natural regeneration?
2. What are the advantage of Natural regeneration and methods of regeneration from vegetative parts?
3. What are the advantage, disadvantages of Artificial regeneration and its objective?
4. What are the factors affecting the choice between artificial and natural regeneration.
5. Write short notes on
   1. Coppicing
   2. Pollarding
   3. Root suckers

**Chapter 7**

**Tree Crown Classes and Their Characteristics**

**Dominant**

* crown extends above the general canopy layer for the stand
* crown intercepts direct sunlight across the top and along sides of the upper branches
* crown well developed and large. though usually somewhat crowded along lower branches
* tree diameter usually among the largest in the stand

**Codominant**

* crown within and helping to form the main crown canopy for the stand
* crown intercepts direct sunlight across the top, but only at tips of the upper side branches
* crown well developed, but of only medium size and crowded at the sides
* tree diameter among the upper range of those present, but not the largest

**Intermediate**

* crown extends somewhat into the lower part of the main canopy
* crown intercepts direct sunlight only at a limited area on the top and none at the sides
* crown narrow and short, with limited leaf surface area and a low live crown ratio
* tree diameter within the lower range of those present. but not necessarily the smallest

**Overtopped**

* crown entirely below the main canopy and covered by branches of taller trees
* no direct sunlight strikes at any portion of the crown
* crown small, often lopsided. flat-topped. and sparse
* tree diameter among the smallest in the stand

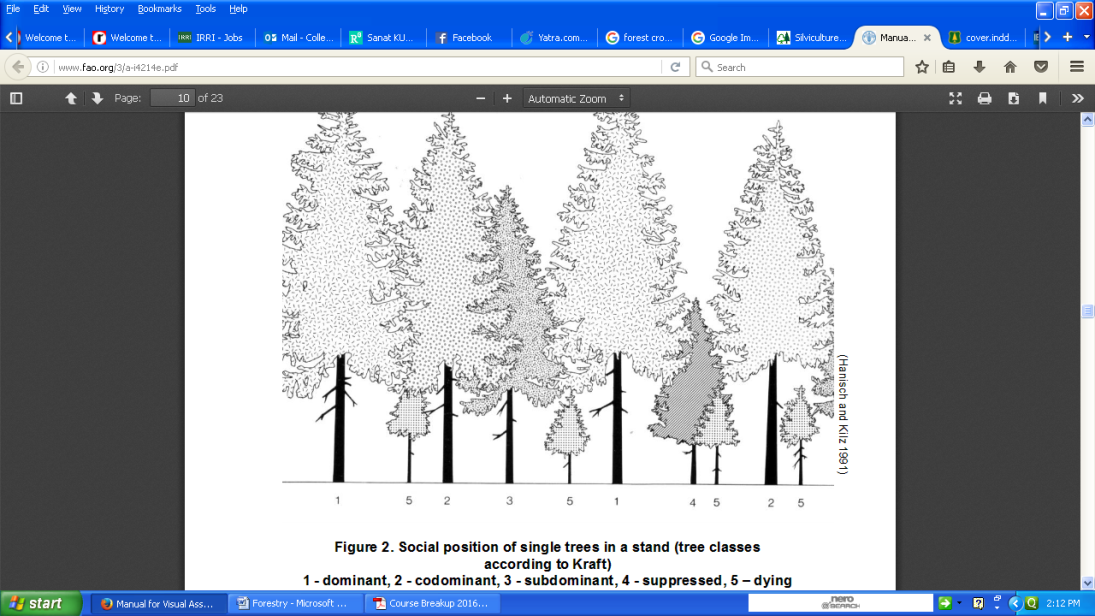
It can also be classified into Five classes of social status are recognized (ICP Forests, 2010):¬

**Dominant**, including free-standing trees with upper crown above the general level of the canopy;

**Codominant,** which includes trees with crowns forming the general upper level of the canopy. **Subdominant**, which includes trees extending into the canopy and receiving some light from above, but shorter than the dominant and codominant classes;

**Suppressed**, including trees with crowns below the general level of the canopy, receiving little direct light from above;

**Dying tree**



**Questionnaires:**

1. What are the tree crown class and its characteristics?

2. Write down short notes on dominant and co dominant tree species.

**Chapter 8**

**Introduction:** The proper development of a forest crop requires food and light from the very beginning. The individual members constituting the crop have to compete for these essentials not only amongst themselves but also with the individuals of the unwanted species which appear on the forest floor by themselves. As the crops grow in age, the requirements of individual members increase and their growth is seriously affected if their increasing requirements of food and light are not met by proper silvicultural treatment, naturally growth and development will be hampered. Therefore, based on age of crop, density, and height required, essential silvicultural treatments should be given for the better growth and yield.

**Tending Operations in Silviculture**

For establishment of the regeneration and subsequent development of the forest crop up to harvesting, several operations are carried out. These operations are carried out in the forest crop at different stages of growth in order to provide a healthy environment for their development. These operations are called tending operations includes:  
 i)Weeding  
 ii)Cleaning  
 iii)Thinning,  
iv)Improvement Felling,  
v)Pruning   
vi)Climber Cutting  
  **i)Weeding:**Weeds may be controlled by following methods:  
a)Mechanical Methods  
b)Biological Methods  
c) Chemical Methods

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

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

**Objective of thinning operation**

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

**Method of Tending Operation - Thinning**

**Following Methods of Thinning can be Adopted:**  
1)Mechanical Thinning,  
2)Ordinary Thinning,  
3)Crown Thinning,  
4)Free Thinning,  
5)Crab’s Advance Thinning,  
6) Numerical Thinning

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

**2) Ordinary Thinning:**

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

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

**Grades of Ordinary Thinning:**

**i) Light Thinning (A Grade):** This is limited to the removal of dead, dying, diseased and suppressed trees.  **ii) Moderate Thinning (B Grade):** This consists in the further removal of defective eliminated stems and whips.  **iii) Heavy Thinning (C Grade):**This consists in the further removal of the remaining dominated stems and such of the defective co-dominants as can be removed without making lasting gaps in the canopy.  
 **iv) Very Heavy Thinning (D Grade):** The distinguishing features of this grade is that, it also takes some of the dominate, subject to the some condition of not making any lasting break in the canopy.

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

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

**Advantages of Crown Thinning:**

Crown thinning offers several advantages over other methods of thinning

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

**Disadvantages of Crown Thinning:**The main disadvantages of crown thinning are

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

**Factors Affecting Tending Operation**

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.

**Looping:** The removal of branches from the top; it may be removal of whole branches. It is usually done for fodder and fuel wood production but tree species should withstand of looping. It effect on bole - is not used for timber production Weeding should be done before weeds have started suppressing the seedlings and seedling have stopped growing, after the growth period is over. Three weeding in first year, two in second year and one in third year but in case of fast growing spp. only one or may be two years only.

**Cleaning**:- It is a tending operation done in a sapling crop, involving the removal or topping of inferior growth including individuals of favored species, climber cutting etc. when they are interfering with the better grown individuals of the favored species. It merges with thinning as saplings grow into poles.

Objectives:-

i. To improve light condition.

ii. To reduce root competition and transpirational water loss.

Method of cleaning:

i. Cutting back of shrubs and herbaceous growth.

ii. Cutting back of the individuals of inferior species.

iii. Cutting back of the malformed or diseased individuals of the desired species.

iv. Singling of coppice shoots of the favored species.

v. Climber cutting

**Improvement cuttings (T.S.I.):-**

Improvement cutting are made in stands which Past the sapling stage for the purpose of improving composition and quality by removing trees of undesirable species, from, condition from the man canopy. The most fundamental characteristics of improvement cutting aside from the fact that they are delayed until the main crop is past the sapling stage, is the elimination of poor trees in favour of good tree. The stems removed include;

1. Inferior species

2. Crocked, leaning, extremely limbs or otherwise badly formed trees.

3. Over mature individuals.

4. Trees seriously injured by biotic or atmospheric agencies.

**Questionnaires:**

Short notes

1. Thinning
2. Looping
3. Factors affecting tending operations
4. Improvement cuttings

**Chapter 9**

**Forest Mensuration**

**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**

* Measuring the effects of silvicultural management practices on stem form, wood quality, tree growth and stand development
* Development of total and merchantable volume equations for estimating the biological asset value of tree stands, and biomass tables for carbon estimation
* Development of non-destructive sampling techniques for volume, biomass and wood quality estimation
* Studying the impacts of long-term environmental changes to the growth of trees and productivity of forests
* Quantification of the impact of anthropogenic influences on growth and yield through model refinement and adaptation
* Forest observational networks for studying and analyzing ecosystem structure and dynamics
* Use of drones, terrestrial and airborne laserscanning, satellite imagery and other advanced remote sensing techniques for measuring and monitoring trees and forests
* Advanced scientific methods for measuring and monitoring the impact of environmental conditions such as climate change on forest productivity, structure and diversity

**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 and Success of estimating the true value of a qty. It also 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. It is the closeness of a measurement to the average value. It also refers to the deviation of sample values about their mean.

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

⚫A² = B² + P²

**Diameter measurement and its significance**

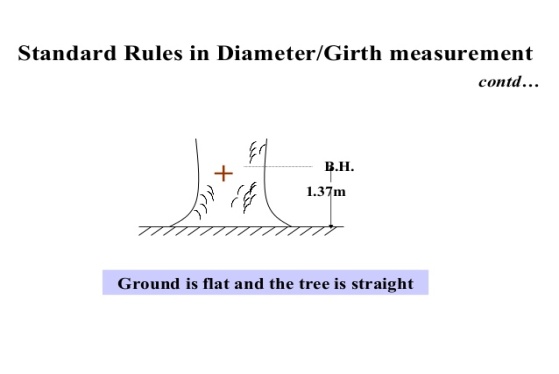
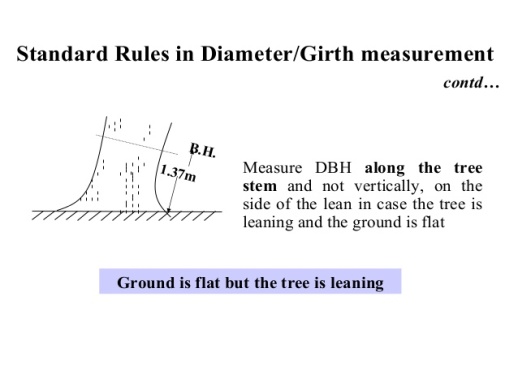
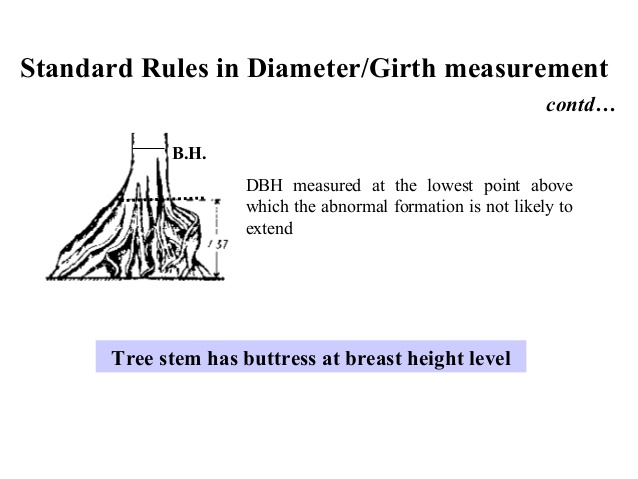
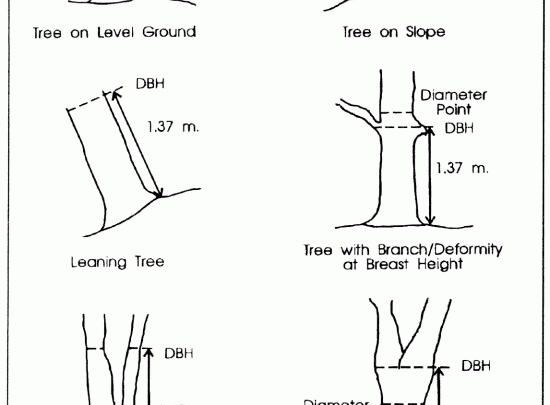
A diameter is a straight line passing through the center of a circle or sphere and meeting at each end of circumference or surface. The most common diameter measurements taken in forestry are of the main stem of standing trees, cut portions of trees and branches. Diameter measurement is important because 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.

**Rules of DBH measurement and instrument used**

****

* 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.

**Wooden Scale**

Wooden scalele is a flat wooden piece marked in centimetres and millmetres. It is a flat wooden piece marked in centimetres and milli metres. It is available in two sizes, 30 cm and 60 cm. The 30 cm wooden scale is about 3cm wide but the 60 cm about wooden scale is about 1.5 cm wide has folding arrangement at every 15 cm length. It is used to measure diameter of stump or end section of logs exposed as a result of cross cutting. It is also used in stump analysis for measuring rsdius at successive decade marks. Rules followed for dia measurement.

1. Diameter should be measured along line passing through piths. In case of eccentric stumps or logs, two diameters one along major axis s and other at right angle measured.
2. When end is worn off by continuous use measurement should be taken from 1st centimeter not from zero mark and ultimately to deduct from one cm from scale.
3. Scale should be placed on edge so that the ends of the line to be measured coincide with mark of the scale
4. While reading eye should be just above the mark i.e., the line joining the eye with the end of the line being measured should be perpendicular to the line.

**Diameter tape**

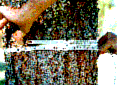
The diameter of a tree cross section may be obtained with a flexible tape by measuring the circumference of the tree and dividing by π(D=C/ π). The diameter tapes used by foresters, however are graduated at intervals of π units (in or cms), thus permitting a direct reading of diameter. A diameter tape 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.

Precautions of using tape:

1. Tape should not be old nor stretched with the end broken off. If end broken off measurement to be taken from next centimeter or inch mark and length to be deducted.
2. It must lie flat against the tree and not in twisted manner.
3. It must be in a plane perpendicular to the axis of the tree. When tape does not cover perpendicular to tree axis then girth is over estimated and then correction factor used to get correct one with principle error in girth is 50% to that of diameter. Deviation 10% from horizontal plane means error 0.77% in girth and 1.6% in basal area and 1.54% in diameter.
4. After swinging the loose end of tape round tree care to take to see that no limber or branch of nearby shrub has vitiated girth measurement.
5. After tape swung round, the end of the tape in right hand of measurement should be brought under starting point of the tape in he left hand to enable correct reading of girth or diameter.
6. Tape should neither trail on ground nor rolled at wet or twisted condition.



**Adavntages of tape:**

1. It is convenient to carry
2. It does not require constant adjustment
3. One measurement is needed even in case of irregular trees.
4. When log lying on ground two diameter measurement by calliper not feasible so measured by tape.
5. Error of tape is always positive and systematic so easily corrected
6. Since tape measures whole circumference rather than two diameter in case of calliper so former covers entire shape to get the reading.
7. Calliper reading sometimes vary with observer due to the 2 points taken fixed for all but tape is universal for all observers covering entire periphery.

**Disadvantages:**

1. If the tree has rough bark the tape exaggerates the diameter or girth measurement
2. It is slower to use particularly in dense shrub growth
3. Sometimes due to one could not look entire periphery knots or swelling over estimated on ignorance
4. If tape to swing round the tree, sometimes it violates the perpendicular axis of the tree.
5. Difference in tension of the tape due to elasticity affects true diameter or girth measurement.

**Calipers**: Calipers are comprised of a fixed arm, scale and moveable arm. The fixed arm is placed along one side of the tree at the desired height. The moveable arm is then placed flush against the other side of the tree and the scale is read directly. The calipers must be located perpendicular to the stem axis. The length of the caliper arms must be at least half the diameter of the tree. Biased estimates (underestimates) of the diameter will result if the arms are less than half the tree diameter. This limitation may restrict the use of calipers to smaller trees - the large diameter trees often found in natural eucalypt forests would require calipers arms in excess of 1 m which would be inconvenient. There are a wide variety of calipers available. The most widely used type is the light, hardwearing, metal alloy caliper

**Method of use**

The handles of the two arms of calipre are held in 2 hands. The movable arm is then tilted inwards so that it can move freely and moved in that between them without touching. The movable is shifted towards tilted position so that the tree touches the fixed arm and movable arm. The movable arm is slowly brought to perpendicular position to the graduated scale and pressed so as to squeeze out any loose bark as well as ensure that there is no gap between the arms and the tree.

**Precautions:**

1. Movable arm should be well opened and must not be forced on the tree.
2. The reading must be taken before callipre is removed from the tree
3. If cross section is more or elliptical it is necessary to measure 2 diameters one major and another minor axis of the ellipse. The two should be right angle to each other and diameter tobe average of these.
4. In case of elliptical shape they must be measured along the real major and minor axes. So major axes must be at proper position and minor perpendicular to it.
5. Calliper must be placed at right angle to axis of the tree. If the plane of the callipre isinclined byanangle θo, the measured becomes D sec θo. The error will be Dsec θo –D.
6. The two arms of the callibre must be i contact with the tree. If the movable arm is not perpendicular to the scale arm and deviation is θo, measured diamwter wil be - or + D tan θo/2
7. Two arms must be in contact with tree, scale area should touch tree also. If this precaution is avoided by – or + L/D x tan θo X 100

Advantages of Calliper:

1. Diameter can be read in cm or mm making useful for prercise scientific work
2. Points of arm touching the tree are always in right and irregularities if any to be avoided
3. By firmly pressing against bole the loose bark is crushed irregularity due to bark avoided.
4. It is useful by unskilled labourers too.
5. Error may be positive or negative, chances is that they may neutralise to give more accurate result.

DiaAdvantages of Calliper:

1. They are not accurate when not properly adusted
2. Callipers sufficient in size to measure large trees are very awakward to carry and handle.
3. Two measurements have to be taken on every tree to get the correct diameter, in steep hilly terrain measurement of of the second diameter is very difficult.
4. Movable arm oftensticks when the scale is wet or dirty thus wasting a lot of time.

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.

**Realationship between diameter and girth of tree**

Of course the ratio of girth and diameter is 0.3182 but in case of trees being irregular cross section sothis ratio is less than 0.3182. Species wise it is different as below.

**Some more instruments for upper stem diameter measurement**

1. **Ruler (upto 2m ht):** Simple board of 150cm x 10 x 1cm with 1 meter road attached at middle on road detachable handle of 2m can be fitted. Board with diam mark withy black paint. Ruler sees diameter through horizontal distance of 10m awayy from tree. Keeping perpendicular to the line of sight and the left edge of rular in line with the left edge of stem in relationship to observer the diameter can be read on the righjt hand part of the rular.

Tree

10m

Observer

1. **Binoculars (more than 2m upto 8m or12m height)**

Here calliper mounted on poles or with help of telescopic ladder can be used. One such calliper is the finished parabolic calliper mounted on telescopic graduated poles. One arm straight other parabolic but does not have movable arm like ordinary calliper. In order to measure the diameter of a tree at a perpendicular height the telescopic pole is graduated pole is adjusted to that height and calliper held perpendicular to the tree. Yhen, a slight parallel to the arm of the calliper taken on the parabolic arm gives the diameter of the tree.

**3.** **Dendrometer (for more greater height)**

This is optical instrument for diameter measurement taken at any point upto the stem beyond the reach of forester well equipped with calliper or dia tapes. It has devised to variations of 3 main classes: optical fork, optical callipers, and short base range finder.

Other instruments for upper stem diameter of tree **are Spiegel relaskop, tele relaskop, wheeler pentaprism and Swedish bark gauge**. Swedish bark gauge measures variation in thickness of bark to calculate volume. Here dia and girth measured at over bark. There is conversion of DOB to DUB or GOB to GUB.

**Chapter 10**

**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

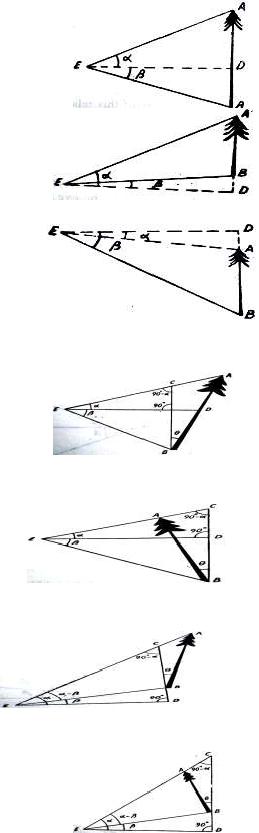
Where,

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.

**Chapter 11**

**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 tanα + BD = BF tan α + 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 α + ED tan β = ED (tan α + tanβ)

=EB Cosβ (tan α + tanβ)

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

AB = AD-BD

=ED tan α – ED tan β = ED (tanα-tan β)

=EB cos β (tanα-tan β)

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

AB = BD – AD

=ED tan β – ED tan α = ED (tan α + tan β)

=EB cos β (tan α + tan β)

**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 (α+β)/sin [ 90-(α- β)]

=EB Sin (α+β)/cos (α- β)

**(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 (α+β)/sin [ 90-(α- θ)]

=EB sin (α+β)/cos(α- θ)

***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 (α-β)/sin [ 90-(α+θ)]

=EB sin (α-β)/cos(α+θ)

**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 (α-β)/sin [ 90-(α-θ)]

=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)

**Chapter 12**

**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.

**Questionnaires:**

1. What are the different types of principles for height measurement of trees? Write about non instrumental methods for height measurement of trees.
2. Diagrammatically explain the standard rules governing measurement of diameter or girth at breast height.
3. Write down the principles of height measurement.
4. Define crown length, total height and bole height of the tree.

**Measurement of Form**

**Tree stem form**

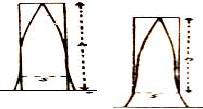
* **Form**is the rate of taper of a log or stem
* **Taper**is the decrease in the diameter of a stem of a tree or of a log from base upwards.
* The taper varies not only with species, age, site and crop density but also in the different parts of the same tree.
* Basal portion of the tree corresponds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

**1.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.

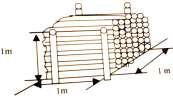
**2.Behre`s formula d/dbh = l/a+bl**

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. **Measurement of length, diameter and sectional area of logs**

* http://www.htmlpublish.com/newTestDocStorage/DocStorage/6a77acb01e734958b7cba35cb47f986d/pdf-to-word_images/pdf-to-word12x1.jpgThe 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 =*π*d2/4

**Chapter 13**

**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 | Volume of full | Volume of | Remarks |
|  | Solid | Solid | frustum of solid |  |
|  |  |  |  |  |
| 1 | Cylinder | Sl | Sl | …… |
|  |  |  |  |  |
| 2 | Paraboloid | Sl/2 | S1 +S2 X l | Smalian’s |
|  |  |  | 2 | Formula |
|  |  |  | Sm X l | Huber's formula |
|  |  |  |  |  |
| 3 | Cone | Sl/3 | S1+S2+√S1S2 X l |  |
|  |  |  | 3 |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 4 | Neiloid | Sl/4 | S1 +4Sm+S2 X l | Prismoidal or |
|  |  |  | 6 | 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.

**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 wood. |

* a piece of wood = wt. of same volume of water or = density of wood/density of water

**Measurement of Staked volume**

* 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.

**Biomass Table and Equation**

**Biomass measurement (Root, leaf, stem and branch Biomass)**

* Biomass is the weight of the above ground vegetative matter produced per unit area. Thus, the wood, their branches, bark and leaves produced by trees, shrubs and other vegetation growing above the ground are included in biomass but it does not include roots, tubers etc (old definition).
* All the plant materials ranging from tree stems, twigs, flowers, leaves, roots, grasses and litter are biomass.
* In [ecology,](http://en.wikipedia.org/wiki/Ecology)**biomass**refers to the accumulation of [living](http://en.wikipedia.org/wiki/Life) matter. That is, it is the total living biological material in a given area or of a biological community or group. Biomass is measured by weight, or by [dry weight,](http://en.wikipedia.org/wiki/Dry_weight)per given area.
* In order to manage the forest scientifically, estimates of present stocking and potential productions are required. The use of biomass as a management tool is a relatively new concept.
* Many of the products available from forests in the middle hills of Nepal, such as fodder, compost material and firewood are quantified in terms of weight rather than volume. The parameter to be measured and the nature of the components for which biomass estimates are to be derived depend on the forest types. In Nepal, the forests can be categorized in to three types for this purpose. They are:
* Natural broadleaf forests with mixed species
* Coniferous forests both natural and plantations
* Broadleaf plantation of single and mixed species
* The general methodology and models for determining biomass estimates are common to all forest types.
* Diameter breast height is the recommended predictor variable. sometimes height is also considered. However, for species which have a very low branching habit or species in a coppiced broad leaf natural forest, diameter measured at 0.3m from the ground level is a better predictor.
* It is necessary to carry out destructive sampling to establish correlations for estimating biomass of standing trees.
* About 30 trees should be selected, felled and separated into main stem, branch wood, twigs and leaves

The main stem should be considered up to the thin end of 10 cm girth or 3.18 cm dia. The rest should be included in branch wood. The felling should be done as close to ground level as possible. Separate portions should be weighted immediately after felling. The felled wood loses moisture very fast. Disc samples should be collected for oven-dry weight.

**Regression equation method**

Process of constructing a Biomass table:

* Selection of tree and tree measurement (Measure diameter at breast height and height of sufficiently large numbers of trees) –destructive sampling.
* Weight measurement (green and oven dry weight measurement)
* Model formulation
* Feed the data in to the SPSS (Statistical Package for Social Science) or MS Excel
* Model selection/ Choosing the best model and verifying the accuracy of the model constructed.

**Model selection and evaluation**

* Several statistics were used in comparing and evaluation the candidate regression model
* Adjusted co-efficient of determination (R2adj)
* Significance of the parameter values
* Homogeneity and distribution of the residuals
* Root Mean Squared Error (RMSE)

**Biomass equations**

* Many forms of regression equations have been used by many workers.
* Equations may be linear, quadratic, cubic, power, logarithmic and exponential etc
* Some models are

|  |  |
| --- | --- |
| B = a + bD, | B = a + bD + cH |
| B= a + d D2H, | lnB = a + b ln(D) + c ln(H) |
| lnB = a + b ln(D) |  |

Widely used biomass equation is, B or W = a + bD2H

Where, B = Biomass in kg, D = diameter, H = height, a = regression constant, and b &c = regression coefficient

**Biomass equations used in Nepal**

* Model equation, ln Y = a + b ln X, has been suitable for calculating the biomass, where Y = oven dry weight in kg and X = dbh
* Model equation, ln W = a + b ln dbh, (for plantation species and natural forests) where W = Green weight of tree components (biomass) in kg, dbh = over bark diameter at breast height in cm, a and b = coefficient of the model

**Biomass Tables**

For plantation species- Dalbergia sissoo (oven dry weight in kg)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Dia. | Weight (kg) |  |  |  |
|  | (cm) |  |  |  |  |
|  | Stem | branch | foliage | Total |
|  |  |
|  |  |  |  |  |  |
|  | 1 | 2.49 | 0.66 | - | 3.16 |
|  |  |  |  |  |  |
|  | 5 | 12.69 | 2.72 | - | 15.50 |
|  |  |  |  |  |  |
|  | 10 | 41.46 | 7.57 | - | 49.28 |
|  |  |  |  |  |  |

For natural forest type (fresh green weight in kg) – *Castanopsis indica* (Dhale katus)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Dia. | Weight (kg) |  |  |  |
|  | (cm) |  |  |  |  |
|  | Stem | Branch | Foliage | Total |
|  |  |
|  |  |  |  |  |  |
|  | 1 | - | 0.2 | 0.3 | 0.5 |
|  |  |  |  |  |  |
|  | 5 | 7.0 | 2.4 | 3.7 | 13.10 |
|  |  |  |  |  |  |
|  | 10 | 37.10 | 12.90 | 10.5 | 60.50 |
|  |  |  |  |  |  |

Source: Nepal Forestry Handbook, 2002

**Volume and Bio-mass of trees and products**

* Volume Table
* To estimate volume of stand, one can measure directly the volume of each tree in a stand and add all figures together. On large stands this is practically difficult. Therefore, the use of volume table is necessary in that case.
* A volume table is a table showing for a given species the average contents of trees, logs or sawn timber for one or more dimensions.
* Volumes may be listed for some specific portion of the stem only, or for the total stem.
* The volume tables are based on the actual measurements of a large number of trees and provide volume estimate of the same species on the assumption that the trees of the same species with the same dimensions will have the same volume.
* Volume tables do not give exact volume of an individual tree because the volume of the individual tree may be different from the average, which is based on several individuals.
* The volume of a tree mainly depends on three variables i. e. diameter, height and form. Out of these variables, diameter at breast height is the most important because
* of its ease of measurement.
* The volume tables give the information on the volume of the product and beside this, give the following information:
* Name of species
* Locality from which the data were collected
* Method of compilation and collection
* Mathematical equation
* Applicability of the table

**Types of Volume Tables**

* Trees with identical breast height diameters and total heights, even for the same species, do not necessarily have the same volume.
* Therefore a single universal volume table that would apply to all conditions and species is not possible. There are some basic factors that cause variation in volume.
* Therefore, volume tables can be classified according to the number of variables used, scope of their application and kind of outturn.

**Volume tables based on number of variables**

* ***Volume table based on one variable: dbh alone***
* •In this volume table, trees are classified by dbh (ob) only.
* •These volume tables show average volumes of trees by diameter classes.
* •It is called local volume table. These are easy and quick to use.
* •The common model for this type of volume table is
* V = a + b (g) or V = a1 + b1 (d2)
* Where, v = volume over bark (ob), g = basal area ob at bh, d = diameter ob at bh and a, a1, b & b1 are constants to be estimated.

**Volume table based on two variables: dbh and height**

Applicable to larger/wider areas.

These volume tables give volumes of trees by diameter classes as well as by height classes pertaining to the total height of the trees.

It is called general volume table

The common model for this type of volume table is

V = a + b(d2h) or V = a + bd2 + ch

Where, v = volume of ob, d = diameter ob at bh, h = height of tree and a, b & c are regression constant to be estimated.

**Volume table based on three variables: dbh, height and form quotient.**

It is called the form class volume tables.

These volume tables are more accurate but are expensive and difficult to construct and use.

The common model for this type of volume table is

V = a + b1 (d2h) + b2q

Where, V = volume of tree, h= height, d = diameter at bh, di= diameter at height i above ground level, q = di/d and a, b1, & b2 are regression constant to be estimated.

**Volume tables based on scope of application**

**General volume table**

* based on two variables i.e. dbh and height, and on the volume of trees growing over a large geographical area.
* It is applicable to a wider range of distribution of species.
* It shows volumes of trees by diameter classes and in each diameter classes by height classes.
* These tables are used for deriving local volume tables.
* These tables are prepared from either graphical method or regression method.

**Regional volume table**

compiled from measurement of trees growing in a region and limited application than general volume tables.

**Local volume table**

* based on one variable i.e. dbh and compiled from the measurement of trees growing in restricted locality.
* applicable to limited or restricted area only.
* These are either prepared directly from field data or derived from general volume table, either by graphical method or regression method.

**Volume tables based on kind of outturn**

**Standard Volume Tables**

⚫give separately the estimated outturn in the form of standard timber.

⚫The volume is given in terms of round timber and includes volume of stump.

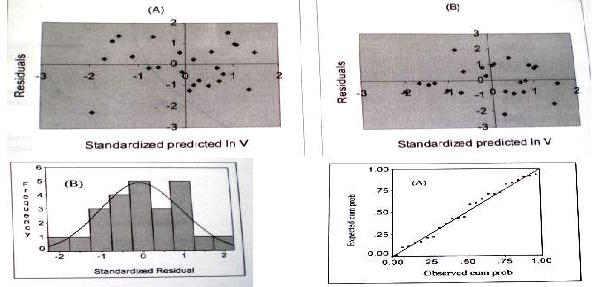
**Commercial Volume Tables-** the contents of round timber are given as volume measured down to a thin end diameter to which conversion is done,

⚫the stump volume being omitted.

**Sawn outturn tables-** contents of sawn timber are given as volume measured down to a thin end diameter to which conversion is done, stump volume being omitted.

**Assortment tables-** give volume in round down to various stated thin end diameters. Eg. Standard timber volume and commercial volume table.

**Sawn outturn assortment tables**



Assortment table and give sawn outturn in the number of standardized pieces instead of volume in round.

**Method of Preparation of volume tables**

* Graphical method
* Regression equations method or the method of least squares fit Regression method is preferable due to its easy application through computers.
* **Regression equation method**
* Process of constructing a volume table:
* Measure diameter at breast height and height of sufficiently large numbers of trees.
* Compute the volume of selected sample trees representing the population (using formula, V = *πd2h/4*or others).
* Prepare a table showing diameter, height and volume
* Model formulation
* Feed the data in to the SPSS (Statistical Package for Social Science) or MS Excel
* Model selection/Choosing the best model and verifying the accuracy of the model constructed.

**Model Selection**

Several statistics were used in comparing and evaluation the candidate regression model.

**Adjusted co-efficient of determination (R2adj)**

* R2 adj. = 1-(1-R2)(n-1)(n-p)
* Where, R2 = coefficient of determination, n = total number of observations and p = number of parameters used in regression model

**Significance of the parameter values**

* The significance test of estimated fixed model parameters tested whether the true value of the parameter is zero or not.
* If the absolute test value was greater than tabulated value i.e. the p-value was less than 0.05, the parameter was treated was significant.

**Homogeneity and distribution of the residuals**

Plotting of the residuals from the model over predicted values or independent variables should show a random, constant variance pattern around a residual value of zero.

**Root Mean Squared Error (RMSE)**

RMSE = √∑ (Yi-Yi)2n – p

Where, Yi and Yi are the observed and predicted values respectively; n is the total number of observations used to fit the model; and p is the number of parameters.

**Preparation of General volume table from regression equation method**

* Measure diameter at breast height and height of sufficiently large numbers of trees.
* Compute the volume of selected sample trees representing the population (using formula, V = *πd2h/4*or others).
* Model formulation

Several linear and non-linear model formulation and their performance evaluation

1.V = a + bD + cH

2.V = a + bD2H

3.V = a + bFD2H

4.V = a + bD2 + cD2H +dH2

5.ln(V) = a + bln(D) + cH

6.ln(V) = a + b ln(D2H) etc,

Where, V = volume, D = diameter at bh, H = tree height, F = tree form, a = regression constant; b, c & d = regression coefficient

**Preparation of local volume table**

* Graphical method or
* Regression equation method

In both of these above methods, local volume tables may be prepared either directly from basic data of diameter and volume of trees or derived from the general volume tables of that species.

**Graphical method based on basic data collected from field**

* In this method, the diameters at breast height and volumes of sufficiently large number of trees are measured and recorded by diameter classes.
* The average volume for each diameter class is worked out and it is then plotted against the mean diameter of the class and smooth curve is drawn through these points.
* It is seldom followed because it is easier to derive local volume tables from a general volume tables.

**Derivation of local volume table from general volume table by graphical method**

Local volume table is derived from a general volume table by localizing the heights by dbh classes using the following procedure.

* Measure the heights and dbh values of a sample of trees representative of those to which the local volume table will be applied and record them accurately.
* The figures of a general volume table are plotted on a graph paper showing against the middle of diameter classes for each height class separately.
* Diameter and height figures of field data are then plotted on the same graph by taking the diameters along x-axis and then interpolating the height against these diameters in between the height curves of general volume tables
* Having plotted all points, a smooth curve is drawn through these points.
* The curve so obtained is the desired local volume table curve and represent relationship between diameter and height.
* From this curve, volume may be read at the middle of diameter classes and tabulated to give diameter classes and volume. This table is called local volume table.

**Regression Method**

Local volume table can be prepared by regression equation method either from basic field data directly or by derivation from the regression equation of the general volume table.

**Regression equation from the basic field data directly**

Some regression equations or models are first prepared from the basic field data and out of these models, the best model is selected for preparation of local volume table.

**Some models:**

* V= a + bD
* V = a + bD + cD2
* ln(V) = a + bD
* ln(V) = a + b ln(D) etc.
* Where, V = volume (m3), D = diameter of trees (ob) at bh, a = regression constant, b & c = regression coefficient, ln = natural logarithms
* The different models used for regression analysis of volume on diameter may be linear, quadratic, cubic, power, logarithmic and exponential etc.

**Derivation of regression equation for local volume table from the regression equation of the general volume table**

* Instead of developing regression equation for the local volume table directly, it can also be derived from the regression equation of the general volume table for that species.
* For eg. Suppose the general volume equation is V = a + bD2H and the height/diameter relationship equation for any locality is H = c + dD + eD2, the local

volume equation will be: V = a + bD2 (c + dD + eD2)

V = a + bcD2 + bdD3 + beD4 V = a + b1D2 + c1D3 + d1D4

Where, a = regression constant, b1, c1 & d1 are regression coefficients.

**Difference between local volume table and general volume table**

|  |  |  |
| --- | --- | --- |
| SN | Local Volume Table | General Volume Table |
|  |  |  |
| 1 | Based on the average volume of | Based on the average volume of trees |
|  | trees growing in a restricted | growing over a large geographical area |
|  | locality. |  |
|  |  |  |
| 2. | Based on One variable i.e. dbh | Based on two variables i.e. dbh and |
|  |  | Height |
|  |  |  |
| 3. | Applicable to restricted localities | Applicable to a wider range of |
|  |  | distribution of species |
|  |  |  |
| 4. | Show volumes of trees by | Show volumes of trees by diameter |
|  | diameter classes | classes and in each diameter class by |
|  |  | height classes |
|  |  |  |
| 5. | Can be derived from GVT | Can’t be derived from LVT |
|  |  |  |

|  |
| --- |
|  |

**Questionnaires:**

1. Define Volume table and methods of preparation of volume table.
2. Write down the difference between local volume table and general volume table.
3. What is Quarter girth formula and how the solid volume of firewood can be measure?
4. Write short notes on form factor, form quotient, form class.

**Chapter 14**

**Introduction to Agroforestry**

Social forestry pertains to those areas and forest which are manmade. Agroforestry is conspicuously and important part of Social forestry and is it a dual system of production i.e. production of forest crops and food crops, fodders or medicinal plant becomes possible. It meets simultaneously at least two requirements of the participating persons. Agroforestry is defined as a sustainable land management system which increase the overall yield of land, combined with the production of crops (including tree crops) and forest plants and animal simultaneously or sequentially on the same unit of applies management practices that are compatible with the cultural practice of the local population. Thus in Agroforestry co-existence of farm and forestry is adopted on a scientific basis and consequently, the total yield of land is raised significantly.

Present status of forest in India is as follows:

• Half of the Forests in India are denuded, various degrees due to increased human activities.   
• India's fast growing population stands at a count of more than 1000 in. and cattle population about 400 m, in which demands for huge amount of food, fodder, timber, fuel, Medicines, employment etc. It has been internationally acknowledged that 30 to 33% of the total geographical area must be under good forest cover.   
•For balance environment and ecosystem  
• All the above situation calls for massive programme of Afforestation and planting with people’s participation. This programme should attempt is restore ecological balance and meet the various needs of rural people. This is feasible only if tree growing become a people’s programme which brought to be combined with agriculture.  
• The forest land area of 75 in ha under forest cover was not adequate to maintain good environment. It was therefore, rightly resolved through a National Policy Resolution in the year 1952 to add 35 m ha to the forest cover and to bring 33% of our land under forests. The decision though wise, timely and far-sighted, was never implemented with the same spirit.

**Objective of Agro-forestry**

* To manage land efficiently so that its productivity is increased and restored.
* To use available resources efficiently and economically
* To generate employment opportunities for rural peoples.
* To provide raw material for small cottage industries in rural areas.
* To raise the supply of fuel in the rural areas at convenient distance for consumer. In India 70 million tons of dried cow dung is used every year, which can be diverted for natural organic fertilizer moreover undue pressure is on traditional forest for obtaining fuel wood.
* Agro-forestry aims to raise the supply for small timber used by villages for agricultural implements, house construction and other domestic purposes. In this way Agroforestry can meet this requirement of the rural population and reduce pressure on forest.
* One of the main objectives of Agroforestry is to raise the production of food crops, legumes and tuber to meet the rapidly growing food requirements of the Indian population.
* Agroforestry aims at promoting production of, vegetables, pulses, milk and meat. Thus it can raise the Nutritional value of food, which is urgently, require for mankind in our country. Average Indian gets 2000 calories when 3000 calories require per day.
* Agro-forestry program helps in obtaining an ecological balance in rural areas and thus it may be consider a matter of great significance for a country like India.
* Preservation of humidity in cultivable lands and check soil erosion. Increase productivity of land. In drought prone areas Agroforestry reduces insecurity of the agriculture; in such areas the dual system of production of tree and grasses ensures stability with productivity of land.
* Supply of fodder for vast population of livestock. For proper feeding to livestock increase supply of fodder is urgently required. Large supply of milk and meat is achieved from livestock and poultry when fodder and feeding is proper.

**Scope of Agro-forestry In India**

There is tremendous scope for Agroforestry because India has achieved self-sufficiency in food production. Now its attention is becoming more focused on the ecological problems and shortage of fuel, fodder and other outputs as well as unemployment. Agroforestry has vast scope in meeting this requirement through multipurpose tree species as:

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

**Benefits from Agro-forestry**

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

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

**Economical Benefits:**

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

**Social Benefits:**

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

**Limitations of Agro-forestry**

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

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

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

**Socio-economic Aspect of Agroforestry**

1. Requirement for more labor inputs, which may cause search at times in other farm activation.  
2. Competition between food or fore crops which could cause aggregate field, to be grown than those of single crop.  
3. Longer period required for trees to grow to mature and acquire an economic value.  
4. Resistance by farmers to displace food crops with trees especially where land is scarce

**Chapter 15**

**Choice of Species for Agro and Farm Forestry**

Following considerations mainly motivate the selection of species in social forestry.   
(1) Rapid growth  
(2) No competition with field crop.  
(3) Fixation of Nitrogen  
(4) Easy decomposition of litter or leaves  
(5) Fast growth and easy establishment  
(6) Ability to regenerate  
(7) High yield of wood and fodder   
(8) Multiple use of wood like Subabul.  
(9) Plant with deep tap root system   
(10) Plant yielding small timber  
(11) Easy in establishment and ability to coppice  
(12) Capacity to grow under wide range of environment, soil types, rainfall etc.  
(13) For recreation and shade plants with quick growing and give shade and pleasing colour like Spathodia, Gulmohar, Cassia, Jakaranda are selected.

**Questionnaires:**

1. Describe the scope, importance and objective of agroforestry.
2. What are the characteristics for the choice of species in agroforestry?

**Chapter 16**

**Kinds of Land and Site for Agro and Farm Forestry**

The following type of land and sites can be assigned for Agroforestry

(I) Field boundaries  
(II) Along with farm roads  
(III) Along with nala sites  
(IV) Land on which cultivation is difficult  
(V) Old fallow lands  
(VI) Cultivable wasteland  
(VII) Site of cattle shade, kitchen farm, farms of house etc.

In practical we practiced Alley Cropping System is one type of Agri-Silvicultural system where 2 components are woody perennial and herbaceous crops. Some common systems may be

**Classification of Agroforestry**

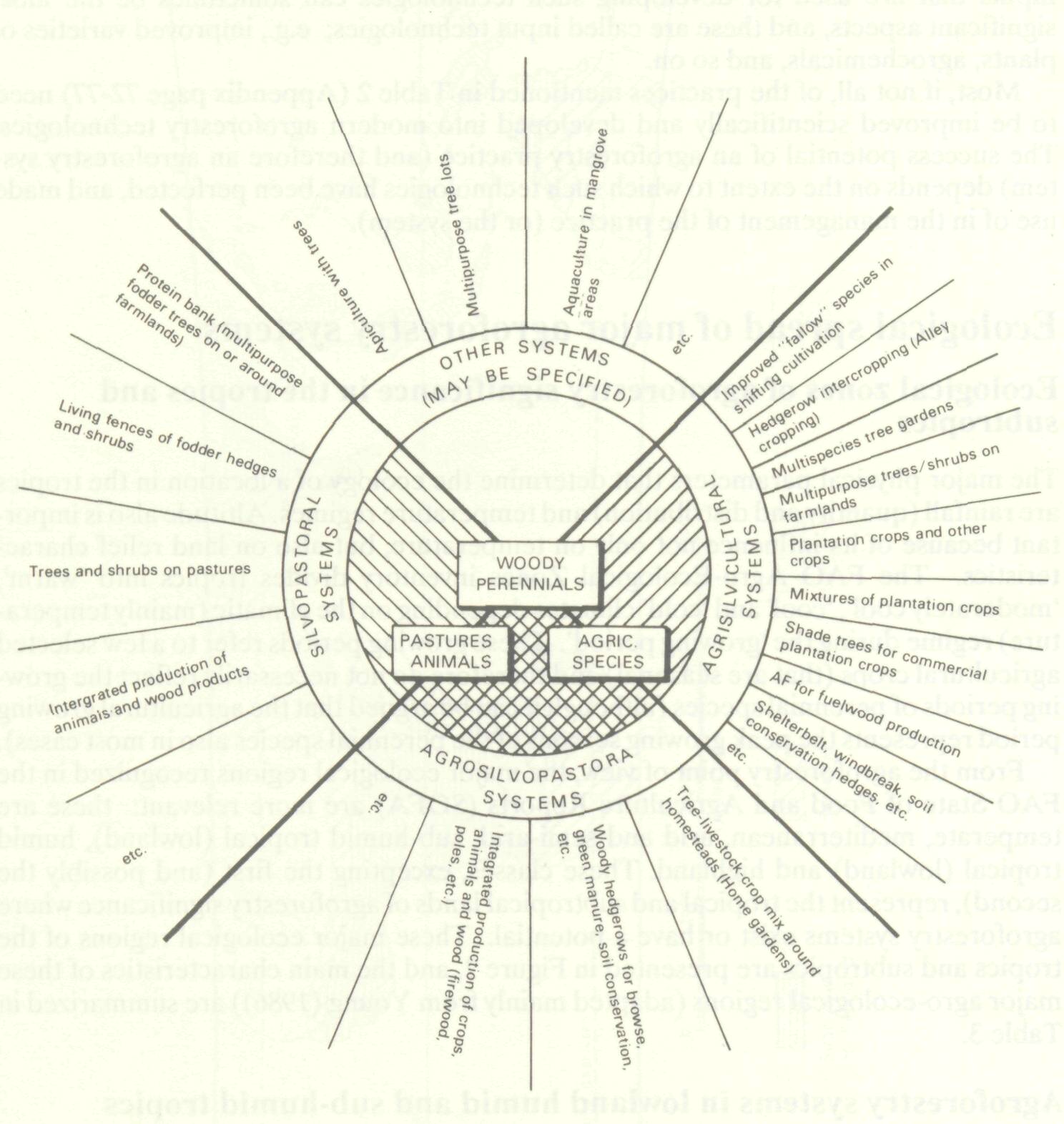
1. Structural Classification (Nature of components or arrangement of components)
2. Structural classification (arrangement of components) refers to the plant components of the system.

Spatial arrangements of plants in agroforestry mixtures vary from dense mixed stands (as in homegardens) to sparsely mixed stands (as in most silvopastoral systems). Moreover, the species can be in zones or strips of varying widths. There can be several scales of such zones varying from microzonal arrangements (such as alternate rows) to macrozonal ones. A commonly mentioned example of the zonal pattern is hedgerow intercropping (alley cropping). An extreme form of zonal planting is the boundary planting of trees on edges of plots and fields for a variety of purposes and outputs (fruits, fodder, fuelwood, fencing and protection, soil conservation, windbreak, etc.). It is also important to note that extreme forms of macrozonal arrangements can also be construed as sole cropping systems; the interactive association of different components, however, can be used as the criterion to decide the limits between macrozonal agroforestry and sole crop systems. Temporal arrangements of plants in agroforestry can also take various forms.

1. Functional Classification (What function an Agroforestry System provides productive or protective)
2. Socio-economic Classification (Quantum of produce obtained from an Agroforestry system, either fully to satisfy household needs or half use and half marketable or completely marketable
3. Agro-ecological or Ecological (Simply Ecological: Based on which Agro-ecological zone the area belongs)

1st two types of classifications are called as structure and functional classification and Last two is called as Classification based on spread and management. The most widely accepted classification is Nature of Components in Structural Classification. It consists of Whether with woody perennial and crop or with Woody perennial and Fodder grass (if animal added it becomes Silvo-Pastoral or Silvi-pastoral) or with all perennial trees, crops and grass (with or without animals accordingly 0 or i given) or others like lac based agroforestry or fish based aquaforestry or honey based api-forestry etc.

**Chapter 17**

**Traditional Agroforestry Systems in India**

Agroforestry is widespread in all ecological and geographical regions of India. The systems vary enormously in their structural complexity and species diversity, their productive and protective attributes and their socio-economic dimensions. They range from apparently simple forms of shifting cultivation to complex home-gardens: from systems involving sparse stands of trees on farm lands (e.g. *Prosopis cineraria* khejri tree - in arid regions of western India) to high-density complex multistoried homesteads of humid lowlands: from systems in which trees play a predominantly 'service' role (e.g. shelter belts) to those in which they provide main salable products (e.g. intercropping with plantation crops). Most of these are anecdotal but in some enough research efforts have been carried out in recent times.

**Shifting cultivation (slash and burn system):**

It refers to farming system in north-eastern high rainfall areas in which land under natural vegetation (usually forests) is cleared by slash and burn method cropped with common arable crops for a few years and then left unattended when natural vegetation regenerates. Traditionally the fallow period is 10-20 years but in recent times it is reduced to 2-5 years in many areas. Due to the increasing trends of population pressure, the fallow period is drastically reduced and system has degenerated causing serious soil erosion depleting soil fertility resulting to low productivity. In north-eastern India many annual and perennial crops with diverse growth habits are being grown. At times annual crops such as potato, rice, maize and ginger are grown in monoculture or mixed culture along with *Pinus kesiya*. Another important attribute of the system is secondary succession of vegetation during fallow period. The tree species which may be considered suitable for afforestation of fallow areas or to intercrop with arable crops must be fast growing preferably nitrogen-fixing and must efficiently recycle available nutrients within the system shortening time required to restore fertility. These may include species of *Acacia, Albizia, Alnus, Casuarina, Erythrina, Faidherbia, Gliricidia. Inga, Leucaena, Parkinsonia, Pilhecellobiuin. Prosopis, Robinia* and *Sesbania.* Thus intercropping under or between fast-growing trees in a fallow phase is one of the approaches while finding alternative to shifting cultivation. A farming-system approach based on the watershed management has been advocated as an alternative to shifting cultivation.

**Taungya system:**

The Taungya system is like an organized and systematically managed shifting cultivation. The word is reported to have originated in Myanmar (Burma) and tauang means hill, ya means cultivation. i,e. hill cultivation. It involves cultivation of crops in forests or forest trees in crop-fields and was introduced to Chittagong and Bengal areas in colonial India in 1890. Later it had spread throughout Asia, Africa and Latin. The taungya (taung = hill, ya = cultivation) is a Burmese word coined in Burma in the 1850s. The taungya system was introduced into India by Brandis in 1890 and the first taungya plantations were raised in 1896 in North Pradesh and the north-eastern hill region. In southern India, the system is called ‘kumari’. It is practiced in areas with an assured annual rainfall of over 1200-1500 mm.

**Home-gardens/homesteads Cultivation:**

A homestead is an operational farm unit in which a number of crops including tree crops are grown with livestock, poultry and/or fish production, mainly for the purpose of meeting the routine basic needs of the farmer. It is an old-age practice in coastal states particularly in Kerala, Tripura, Assam, North-eastern states and parts of West Bengal and Andaman and Nicobar Islands. Although the home-gardens appear to be a mixture of trees, shrubs and herbs, a certain general pattern seems to exist. There is wide variation in the intensity of trees, species and crops based on the size of holding, needs of the people residing in homesteads and micro-climate. Coconut, arecanut, guava, mango, citrus, tamarind, jack-fruit, papaya, banana, moringa, sesbania, custardapple and many multipurpose trees are the major trees found grown in home-gardens. Domestic animals and poultry are the main components of homesteads; therefore, sometimes forages like stylo (*Slylosanthes guianensis* / *S. hamata*), guinea-grass, Guatemala, napier and others are also grown frequently. The components are so intimately mixed in horizontal and vertical strata as well as in time that a complex interaction exists among soil, plants, other aboveground and below ground components, nutrition and environmental factors. There is critical competition both for light and nutrition. The holder chooses his crops and crop combinations based on his wisdom, needs and perceptions acquired over generations of experience. Many multipurpose trees having productive and protective functions are integrated into the system in different spatial and temporal arrangements. Most of these trees closely interact with agricultural crops when grown. These trees include teak (*Tectona grandis*), jack-trees (*Artocarpus spp*.), *Casuarina equisetifolia, Mangifera india, Ceiba pentendra, Leucaena leucocephala, Grevillea robusta, Bambusa arundinacea, Erythrina variegata* and *Gliricidia sepium* (both good support to black pepper). *Thespesia populnea* is common in low lying homesteads and the wood is commonly used for agricultural implements. Mangroves form an essential part of homesteads of backwater areas in lowlands. These are commonly used as fuelwood. Coconut and pandanus (*Pandanus tectorius*) can be commonly seen near canals and backwaters. Palmyrah palm (*Borassus flabellifer*) is common multipurpose palm in coastal Andhra Pradesh. Fish and shrimp culture in backwater channels and in association with mangroves is the main activity in homestead. Thus, multitude of crop species in the homesteads helps to satisfy primary needs of the farmer such as food, fuel, fodder, timber and cash. This in spite of high intensity of cropping also helps to conserve fertility by nutrient cycling or organic manuring or mulching and increased microbial activity in the rhizosphere of crops. Among social benefits are-high family labour utilization and risk minimization. This system also helps in checking soil erosion (due to high intensity of vegetation cover), environmental health and conserving biodiversity.

**Plantation based Agroforestry systems:**

Modern commercial plantation crops like rubber, coffee, poplar, eucalypts and oilpalm represent a well-managed and profitable stable land-use activity in tropics. The scope for integrative practices involving plant associations in these commercial plantations is limited, except during the early phases of plantation when some intercropping is feasible, the commercial production of these crops is aimed at having a single commodity. Some of the plantation crops like coconut, palms have been cultivated since very early times but their economic yield remained low. However, the research attention and commercial yields of these crops have increased substantially. Contrary to common belief - a substantial proportion of tropical plantation crops is grown by small farmers. Most of the coconut production in India, and other countries comes from small holdings, in which coconut-palm is integrated with a large number of annual and perennial crops like clove, cardamom, coffee, cacao, cassava, yams, fodder grasses and legumes. Grazing under coconut and cashew nut is also common. In India, small holders grow cashew-trees (in wider space) with other crops.

In the last two decades, most of the data have come from coconut-based systems in India, related to intercropping under coconuts, integrated mixed farming in small holdings, grazing under coconuts, factors favoring intensification of land use with coconuts and multi-storey tree-gardens. Important cereals grown with coconut include rice, finger millet and maize: pulses such as pigeon pea, green gram, black gram, cowpea, soybean, oilseed crop such as groundnut; root crops such as sweet-potato, yams, elephant foot-yam and taro: spices and condiments such as ginger, turmeric, cinnamon, clove, chilies and black pepper; fruits like pineapple, mango, banana and papaya; cash crops such as cotton and sugarcane, plantation crops such as areca nut, cacao and coffee, Many trees such as species of Erythrina, Ceiba, and Cordia find a place in the system.

**Scattered trees on farm lands:**

The practice of growing agricultural crops under scattered trees on farm lands is old and does not seem to have changed for centuries. Though world-wide list of such trees is long, some of them have received more attention than others e.g. *Prosopis cinaria* in north-western India and Poplars in north India. The species diversity in these systems is very much related to ecology. With increase in rainfall, the species diversity and system complexity increases. Thus, there is a proliferation of more diverse multistoried home-gardens in humid areas and less diverse, two tiered canopy of configurations (trees + crop) in drier areas.

Trees are grown scattered in agricultural fields for many uses such as shade, fodder, fuel wood, fruit, vegetables and medicinal uses. Some of the practices are very extensive and highly developed in India. For example growing *Prosopis cilleraria* and Zizuphus in arid areas; *Acacia nilotica* in Indo- Gangetic plains; Grevia optiva and other tree species in hills of Uttarakhand and HP; *Eucalyptus globulus* in southern hills of Tamil Nadu and *Brossus flabellifer* in peninsular coastal regions. There are strong convictions for the acceptance of these trees on agricultural fields since time immemorial.

Farmers retain trees of *Acacia nilotica*, *Acacia catechu, Dalbergia sissoo. Mangifea indica,. Zizuphus mauritiana* and *Gmelina arborea* are preferred in Gujarat with crops. Farmers in subhumid terai region of Uttarakhand and Uttar Pradesh prefer *Dalbergia sisoo, Syzygium cumnii and Trewia nudiflora.* In Bihar, *Dalbergia sissoo*, *Litchi chinensis* and Mango are frequently grown on fields. Every part of the palm is used by common man: the leaves for thatching, trunk as pillar or timber, fruit is roasted and consumed, the radicle of germinating seeds is roasted, a beverage (alcohol) is extracted from spadix, which is also used to prepare jaggery and vinegar. Other most common trees found on farmers' fields are *Azadirachta indica, Moringa oleifera, Tamarindus indica, Ceiba pentandra. Anacardiuln occidental, Cocos nuciferaand* fruits like banana, custard-apple, guava and pomegranate.

**Trees on farm-boundaries:**

Trees grown in agricultural fields are also often and usually grown on farmboundaries. In northern parts of India, particularly in Haryana and Punjab Eucalypts and Populus are commonly grown along the field boundaries or bunds of paddy fields; other trees which are found grown as boundary plantations or live hedge include-. *Dalbergia sissoo* and *Prosopis juliflora*. Farmerrs of Sikkim, grow bamboo (Dendrocalamus, Bambusa) all along the irrigation channels. In coastal areas of Andhra Pradesh, *Borassus* is the most frequent palm. In Andamans, farmers grow *Gliricidia sepium*, J*atropha* spp, *Ficus, Ceiba pentandra, Vitex trifolia and Erythina variegata* as livehedges. At many places succulents like Agave and many cactoids are grown as common live-fence. Many of the boundary plantations also help as shelter-belts and wind-breaks, particularly in fruit orchards. In Bihar, *Dalbergia sissoo* and *Wendlandia exserta* are most common boundary plantations.

**Wood lots:**

In many parts, farmers grow trees in separate blocks as wood-lots along with agricultural fields. Now the practice is expanding fast due to shortage of fuel-wood and demand of poles or pulp-wood in industry. For example, bamboo poles are in great demand for orange orchards in Nagpur area and Eucalvptus and Poplars for match industries. These days wood-lots are being raised mostly on large farms due to increase of labour costs and labour management, lack of irrigation and risk of crop investments. Wood-lots of Casuarina, bamboo, poplar, Eucalyptus, *Leucaena leucocephala*, red sandal (*Pterocarpus santalinus*) and *Dalbergia sissoo* have become popular in many parts of the country.

**Systems for soil conservation or amelioration:**

About 150 million ha of land in India is subject to serious wind and water erosion, of which 69 million ha are critically affected. About 4 million ha is suffering from degradation due to ravines and gullies 11.3 M ha as riverian land. Coastal sandy areas and steeply sloping lands and more than 9 million ha is salt affected. The deep and narrow gullies are best controlled by putting them to permanent vegetation after closure to grazing. Afforestation with suitable tree species like *Acacia nilotica, Azadirachta indica, Butea moonosperma. Prosopis juliflora, albergia sissoo, Tectona grandis, Bambulsa spp.* and *Dendrocalamus* and other adaptable species such as grasses like *Dichanthium annulatum, Bothriochloa pertusa, Cynodon dactylon* and *Sehima nervosum* will help in stabilizing ravines and gullies and checking their spread. In recent times, due to increase in population pressure these wood-lots have shrunk at a fast rate.

**Alley cropping**

**Multispecies Tree Gardens and Alley Cropping (Hedge Row Intercropping)**

W

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

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

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

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

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

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

**Improved Fallow Species in Shifting Cultivation**

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

Shifting cultivation as the term implies, is a pattern of land use and a system of production of crops under which plots of land are cleared, cultivated for a short period for raising crops, after which the land is allowed to rest longer than the period of cultivation. It is a system of production almost without capital inputs.  
 This system is practiced extensively the north-eastern hill region comprising the states of Assam, Meghlaya, Maniput, Nagaland and Tripura (Arunachal Pradesh and Mizoram). To some extent in Andra  radesh, Bihar, Madya pradesh, Orissa and Kernataka. It is called as JHUM in the north eastern hill region and PODU, in A.P. and Orissa and considered most destructive for forest areas.

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

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

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

**Establishment:**

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

**Windbreaks**

Windbreaks usually consist of multi-storey strips of trees and shrubs planted at least three rows deep. They are placed on the windward side of the land to be protected, and are most effective when oriented at right angles to the prevailing winds. While their length and height may vary dramatically, it is common in the dry savannas and steppes of Africa to plant windbreaks 100 m long or more, with a peak height of 10 m. Small living fences and hedgerows can also act as windbreaks for small sites such as homegardens and nurseries. However, windbreaks are distinguished from boundary plantings and living fences by their orientation, which must face the wind, and by their multistory, semipermeable design. They may conform to roadside, boundary, and floodpLaln lines, but must be specifically designed to slow the wind. Very dense windbreaks may do more harm than good since they will tend to create strong turbulence that will scour the soil on the windward side and damage crops on the leeward side. Conversely, gaps in the trees will channel the wind, actually increasing the velocity on the leeward side and promoting soil erosion and damaging crops. The protected zone created by windbreaks is defined as the area, on both leeward and windward sides, where wind speed is reduced by 20% below incident wind speed. The effective distance of protection is expressed as multiples of the height (H) of the tallest rows of trees. Practical windbreak ffects extend to a distance of 15-20 H leeward and 2-5 H windward of the windbreak; but usually a common calculation of the extent of protected area is 10 H leeward. This means if the trees are 10 m tall, crops up to 100 m in the leeward direction will be protected. The protective influence will diminish with increasing distance from the windbreak. A permeable windbreak will shelter a longer stretch of cropland than a dense windbreak. The most effective windbreaks provide a semipermeable barrier to wind over

their full height, from the ground to the crowns of the tallest trees. An "ideal" windbreak should consist of a central core of a double-row planting of fast - and tall - growing species such as *Eucalyptus* spp., *Casuarina* spp., or neem *(Azadirchta indica),* and two rows each of shorter spreading species such as *Cassia* spp., *Prosopis* spp. or *Leucaena* spp. on botffsides of the central core. *Agave* spp. are also used, especially on the outer rows (away from crop fields). Since the trees change their shapes as they grow, it is usually necessary to mix several species of different growth rates, shapes and sizes in multiple rows. Some fast-growing species should be used to establish the desired effect as rapidly as possible. In addition, some of the trees selected may not be as longlived as others. Fast- and slow-growing species as well as trees with longer and shorter life-spans should thus be mixed to extend the useful life of the windbreak. Mixing species also provides protection against attack from diseases or insects that can easily destroy single-species stands.

Diversifying the species in the windbreak can also bring a wider variety of useful products to local users. A fully developed windbreak can yield wood, 336 *Soil productivity and protection* fruit, fodder, fiber, and honey for sale and home use. Where animals are allowed to graze nearby, at least some of the lower, outer trees or shrubs should be relatively unpalatable, while fodder species may fit closer into the center or along an inside edge where they are not exposed to animals, but can be cut by hand. Neem has been successfully used in Niger; its unpalatable leaves protect it from damage by livestock. Although some trees such as neem, *Casuarina* spp., and *Eucalyptus* spp. are widely used in windbreaks, they should be used selectively. *Eucalyptus* shouldnot be used alone as it has a sparse understory and may negatively affect water availability and crop productivity in the vicinity. Neem is known to shade crops and thus reduce the land available for crop production. On the other hand, people have constructed successful windbreaks with such unlikely trees as cashew *(Anacardium occidentale)* and local *Acacia* spp. The species selected must fit together as a group into a larger overall design that, in turn, complements the local landscape and land-use system. While diversity is important, there are constraints on species choice both for indigenous and exotic species. Environmental hazards such as insect pests (especially termites), wild and domestic animals, poor soil, and drought, will narrow the choice as well as reduce the tree's growth rate. Water management, especially during establishment, will be important, as in any attempt to establish trees in a dry environment. Microcatchments, hand watering, or irrigation should be anticipated.

**Shelterbelt:**

Arid regions witness very high wind velocity throughout the year. Farmers build shelter-belt (kana bundi) by either small dead wood or local vegetation to check wind velocity within safer limits. *Crotolaria burhia, Leptadenia pyrotechnica* and *Aerva pseudotomentosa* bushes are planted in 20-25 m a part rows across the wind direction. Between the lines of these shrubs grasses such as *Cenchrus ciliaris, C. setigerus, Lasiurus sinicus* etc are planted on leeward side of each break. This permanent vegetation helps accumulate sand near them which is again spread in the field. This also helps increase crop yields along the lines.

**Trees on rangelands:**

As pointed out above, *Salvadora oleoides, Capparis decidua. Acacia nilotica, A. leucophloea. P. cineraria, and now Prosopis juliflora* also are most frequent trees on common community grazing lands. In tropics coconut is most common tree on pasture lands. Cattle raising usually involves grazing on these pastures. In some cases special fodder plants including legumes are also cultivated.

**Agroforestry in Recent Past**

Especially during the last 3-5 centuries spectacular improvements have been made in tree plantation. The most important agroforestry practice is known from the Kangeyam tract of Tamil Nadu, where *Acacia leucophloea* + *Cenchrus setigerus* in silvi-pasture system was perfected. Similarly, in ravines of Yamuna and Chambal, trees, shrubs and bamboos with grasses were planted for rearing milk-producing Jamunapari breed of goats and sheep. Scattered trees with khejri or mehndi in association with bajra, jowar and chillies were grown in the semi-arid area of Tamil Nadu. Tree plantation continued as demarcation and control against wind erosion throughout the country. Plantation of khejri trees for various uses on on-farm was a common practice in Rajasthan. In coastal areas, *Casuarina equisetifolia* and other trees were grown in association with crops on farm lands for cash and to generate small timber. Live hedges were common as an agroforestry

**Systematic plantation of Tree Species**

practice in which mehndi, *Agave sisalana* and Euphorbia species were common. In paddy-growing areas *Pongamia glabra* and *Sesbania grandiflora* were grown, lopped annually and their leaves applied to fields as green manure. Application of green manure to paddy field was common in Madhya Pradesh and Uttar Pradesh. In Western Ghats Terminalia leaves were harvested, spread on land, burnt and then paddy, ragi and millets were sown Multistorey homesteads or home-gardens were in existence in Kerala, Karnataka, Tamil Nadu, Tripura, Assam and other North Eastern states as an important agro forestry practice. This practice is still followed in these states.

**Questionnaires:**

1. Write down different classification of agroforestry.
2. Short notes
3. Shifting cultivation
4. Taungya system
5. Homegarden
6. Alley cropping
7. Multiple species garden
8. Improved fallow species
9. Windbreak

**Chapter 18**

**Cultivation Practices of Two Important Species**

**1.*Acacia auriculiformis* Australian Acacia or Akashmani**

**Habitat and Uses**

As currently defined Acacia (family Fabaceae, subfamily Mimosoideae) represents a cosmopolitan genus of 1200-1300 species contained in three subgenera: Acacia, Aculeiferum and Phyllodineae (Maslin, 1995). A. auriculiformis is in subgenus Phyllodineae, a group containing in excess of 900 species. Some authors use Heterophyllum instead of Phyllodineae as the name for the last subgenus. Within subgenus Phyllodineae the species are grouped into seven sections with A. auriculiformis assigned to section Juliflorae (235 species), a group characterized by having flowers in elongated spikes and phyllodes with numerous, often anastomosing, longitudinal veins. However, the proposed new nomenclature has occasionally been used by authors and there are citations in the references to Racosperma auriculiforme (syn. A. auriculiformis). The specific name was published in Hooker's London J. Bot. 1: 377 (1842). It is derived from the Latin `auricula', meaning external ear of animals, and `forma', meaning form, figure or shape, in allusion to the shape of the legume. Natural stands of A. auriculiformis are found in Australia, Papua New Guinea and Indonesia. In Australia it occurs on Cape York Peninsula and in Torres Strait, Queensland, and in the north of the Northern Territory including several off-shore islands (Boland et al., 1990). In Papua New Guinea it occurs in the Central and Western Provinces, and extends into Irian Jaya (Papua Barat) and the Kai Islands of Indonesia. The domestication of *A. auriculiformis* began when it was introduced to Thailand in 1935. It is planted widely in tropical Asia, with extensive plantings in China and India. *A. auriculiformis* is amongst the best performing acacias on slightly to moderately saline, seasonally waterlogged soils in north-eastern. It has become naturalized in western Malesia and *A. auriculiformis* is planted to a lesser extent in Africa and South America. A. auriculiformis occurs in the lowland tropics growing naturally in narrow belts along river banks, where it may be dominant or one of the principal species. It also occurs in small pockets in depressions and in open-forest dominated by various eucalypts and acacias. It is also found in littoral rain forest behind either mangroves or coastal dunes. It occurs as scattered trees in the riparian habitats, tall savannah woodland and in tall open-forest (monsoon forest). It is a component of swamp forest dominated by Melaleuca species, usually on the better drained sites. It is also common in littoral forest. Regular associates in these forests include *Acacia mangium, A. aulacocarpa* and *Melaleuca cajuputi.*

**Uses**

Though not widely used in agroforestry systems because of its spreading and competitive surface rooting habit, intercropping *A. auriculiformis* with peanut, rice, mung beans and kenaf has proved to be successful (Turnbull and Awang, 1997). Pruning of *A. auriculiformis* is recommended to improve light availability to crop plants (Miah et al., 1995). It has been used satisfactorily as a nurse tree in tea plantations. *A. auriculiformis* is sometimes planted in mixture with eucalypts and other trees which do not fix nitrogen to maintain or improve soil fertility. Its leaves (phyllodes) are good for soil mulching. This species is planted to provide shelter along shorelines and for revegetating mining spoil heaps. The spreading, densely-matted root system can stabilize eroding land. It has been used widely in revegetating degraded land and rehabilitating grasslands in India, Indonesia and Vietnam. *A. auriculiformis* is used for shade and ornamental purposes in cities where its hardiness, dense foliage and bright-yellow flowers are desirable attributes. *A. auriculiformis* can be used as a host tree in the nursery propagation of sandalwood (*Santalum album*) (Nasi and Ehrhart, 1996) and is also used as a secondary or tertiary host when sandalwood is established in the field (Fox and Barrett, 1995). *A. auriculiformis* wood has a high basic density and a calorific value of 4700-4900 kcal/kg, which make it ideal for firewood and charcoal. The charcoal is not very heavy, burns well and does not smoke or spark (Wiersum and Ramlan, 1982) with physical properties, calorific value and burning properties described by Yantasath et al. (1993). In Asia and Africa it is planted for fuelwood, and is an outstanding fuelwood species for acid soils (Ryan et al., 1994). The annual fall of leaves, twigs, and branches can amount to 4-6 t/ha which is useful as household fuel (NAS, 1983). The sapwood is yellow and the heartwood light brown to dark red; the timber is fine-grained, often attractively figured and finishes well (Keating and Bolza, 1982). The wood of *A. auriculiformis* makes attractive furniture. It is also suitable for construction work (e.g. framing, flooring), wood turning and carving. Boards may sometimes split when sawn. The crooked and multiple stems which are a common feature of the species largely restrict its use as poles or other forms of timber that require reasonable length. The heartwood is typically hard and durable, but the sapwood is highly susceptible to termite and borer attack and requires preservative treatment when in contact with the soil. Plantation-grown trees are very promising for the production of unbleached kraft pulp (for bags, wrapping paper, linerboard) and high quality neutral sulphite semichemical pulp (for corrugating, medium and higher-grade packaging-type products) (Logan, 1987). It is less suitable for high-yield mechanical type pulps (Phillips et al., 1979) although there is significant variation in pulp-making properties between provenances (Logan, 1987). Large-scale plantations have already been established in Karnataka, India for the production of paper pulp. Although *A. auriculiformis* is not recognized as a fodder species, trees may be browsed by cattle in India and Fiji (Banerjee, 1973; L Thomson, CSIRO, Canberra, Australia, personal communication, 1997). A preliminary study of fodder values has shown that A. auriculiformis meets the minimum requirements for certain nutrients and warrants further investigation (Vercoe, 1989). The bark has sufficient tannins (about 13%) for possible commercial exploitation (Abdul Razak et al., 1981). A natural dye, used in the batik textile industry in Indonesia is also extracted from the bark. Lac insect culture using the species as a host plant is possible. Edible mushrooms occur in plantations in Thailand and Vietnam. *A. auriculiformis* flowers are a source of bee forage and contribute to honey production (Moncur et al., 1991).

**Regeneration**  
 A. auriculiformis produces large quantities of seed at an early age. Germination is rapid after suitable treatment and typically exceeds 70%. There is an average of 71,600 viable seeds/kg (Doran and Turnbull, 1997). Although A. auriculiformis has the ability to coppice, it is not a vigorous or prolific sprouter and careful management is required to obtain good results from coppicing. Profuse natural regeneration may appear after fire or on disturbed sites in the absence of severe weed competition. In Odisha it is been distributed in the entire state from coast to inland areas. Seedlings grow quickly and reach a height of 25-30 cm in 3-4 months, 6 m in 2 years, and 6-12 m in 3 years under favourable conditions (Turnbull and Awang, 1997). Young seedlings produce 2-3 bipinnate leaves, soon followed by phyllodes. Phyllodes are retained during the dry season; their average life is about 1 year in west Java, Indonesia. Pollination is by insects. Flowering usually starts within 2 years after sowing (Pinyopusarerk, 1990). The yellow flower spikes can be found on individual trees throughout the year but there is usually a distinct peak flowering season that may vary considerably with location. In the Northern Territory of Australia, flowering occurs from April to July with ripe seed available some 4-5 months later in August to October (Brock, 1988). Sedgley et al. (1992) found that peak flowering occurred in February to May at Atherton in Queensland, near Kuala Lumpur in Peninsular Malaysia, and Tawau in Sabah, with ripe seed pods available between October and April. In Java, peak flowering occurs in March to June (Turnbull and Awang, 1997). Mature seed can be collected between August and February in Thailand (Pukittayacamee et al., 1993). A. auriculiformis produces large quantities of seed at an early age. Germination is rapid after suitable treatment and typically exceeds 70%. There is an average of 71,600 viable seeds/kg (Doran and Turnbull, 1997). Although A. auriculiformis has the ability to coppice, it is not a vigorous or prolific sprouter and careful management is required to obtain good results from coppicing. Profuse natural regeneration may appear after fire or on disturbed sites in the absence of severe weed competition.

### Diseases and pests

There are several diseases and insect pests of A. auriculiformis, but none are limiting to establishment on appropriate sites at present (Day et al., 1994). During a recent workshop on diseases of tropical acacias (Old et al., 1997), a number of diseases were identified as potential threats to the future productivity of industrial plantations. These included stem cankers caused by a range of pathogens (Botryodiplodia theobromae, Botryosphaeria spp. and Hendersonula sp.) and most often associated with stem borer damage, pink disease (Corticium salmonicolor) which is most prevalent in high rainfall areas, and phyllode rust (Atelocauda digitata) which has impaired the growth of A. auriculiformis in Australia and Indonesia. It is not susceptible to the heart rot which affects A. mangium (Ito and Nanis, 1997). A root rot fungus, Ganoderma sp., was observed to cause crown dieback and defoliation in A. auriculiformis plantations in parts of West Bengal, India (Barari, 1993). Ganoderma lucidum causes root rot in India (World Agroforestry Centre, 2002) and a species of Cuscuta (Convolvulaceae) has also been recorded as a parasite of A. auriculiformis in West Bengal (Banerjee et al., 1993). Seedlings in the nursery can be infected by powdery mildew (Oidium) especially where there is heavy shading (Harsh et al., 1992).   
Stressed trees are particularly susceptible to attacks by insect pests. A beetle, Sinoxylon sp., can girdle small stems or branches. In Australia, the wood is attacked by borers and termites, and scale insects are prevalent on young trees (Hearne, 1975). Experimental results suggest that A. auriculiformis shows some resistance to termites (Turnbull and Awang, 1997). A. auriculiformis was recorded as host to Xystrocera festiva at two locations in south Sumatra, Indonesia (Suharti et al., 1994).

**Chapter 19**

***Eucalyptus* species**

**Habitats and uses**

An Australian genus comprising 140 species, most of which are found in Australia and some in Tasmania, New Guinea and other islands. Eucalyptus are evergreen species, all more or less aromatic and containing oil glands in their leaves, oil distilled from leaves is of medicinal value. They contain several of the most important timber trees of the Australian continent where they form large tracts of forest, some growing pure and other mixed. Some of them reach gigantic size. Blue gum (Eucalyptus globules) and Pepper mint gum (Eucalyptus regnans) attaining heights of over 400’. Eucalyptus appear to have attracted attention in their home in the early part of 19th century. Then for the most part blue gum were planted in the S. Europe for ornament. Then their economic was value was realized and plantations were formed extensively in the Mediterranean countries, California, Florida. Hawaii and several other parts of the W. Hemisphere in S. Africa and in several other sub-tropical and warm temperature regions throughout the globe. Introduction in India probably dates from 1843 and when a few trees were planted experimentally in the Nilgiris to find out their suitability as fuel. Regular plantations chiefly of E. globules, were commenced in 1956

and have since been extended on a large scale. Numerous species of the genus have since been tried in all parts of India, on the hills and the plain. On the whole ame species or other of Eucalyptus can be grown in any part of India except (i) very moist tropical regions where seedlings damp off in spite of all precautions and (ii) elevation above the winter snow-line where snow break is to be feared. As timber trees Eucalyptus have not come up to expectations in India, but as producers of fuel they are far superior to any indigenous species. The globe gum conferred an inestimable boon on the Nilgiris. Numerous failures have occurred in attempts to introduce Eucalyptus in India because the conditions suited for the different species were not looked into. For low elevations in India only those species which grow in warm tropical parts of Queensland and adjacent northern regions (which carry such well known Indian trees as Bombax, Eugenia, Jambolana, Barraingtonia, Alstonia, Mellotus, Frema, Ficus glomerata and Casuarina) would be suitable. For planting in higher elevations species growing in Tasmania and the southern parts of Australia should be suitable. Example of the latter is the blue gum which has succeeded well in Nilgiris.

**Silvicultural characters**

**Light** – As a rule, intolerant of shade. Many species, however tend to branch in the open. Also, in early young seedlings endure a little shade for a time. Many species coppice well, the most vigorous probably being E. globules. Root system – Spreading Generally wind firm, but many species are liable to become bent, gnarled and stunted in exposed situations. Species tried at higher elevations in the Himalayas are found to suffer from snow break. Thick barked trees do not suffer much from fire but thin barked ones and young trees suffer badly. Those with barks exfoliating in long, dry strips, like blue gum suffer much as the fire ascends through the strips to the crown. Most species have high power of recovery from fire damage. Those damage by produce primordial leaves (e.g., blue gum plantation proofing silvery blue owing to such leaves). The more aromatic Eucalyptus are not readily browsed by cattle. Two species E. corynocalyx (whose leaves are sweetish) and E. gunnii (whose leaves are not strongly aromatic) are browsed by cattle. **Deer** – Has been responsible in Dehra Dun and elsewhere for rubbing against young trees and causing damage. Fencing may be necessary where this form of damage is prevalent. In the Changa Manga plantation, Nilgai browsed seedlings in winter and gnawed the bark in the case of saplings and poles whose leaves were out of reach. The requirements of soil and climate for various species very considerably. Generally speaking, most it not all Eucalyptus grow best on deep fresh soil with a fair amount of subsoil moisture. Many however, accommodate themselves to unfavourable conditions and in such cases their growth is affected.

**Natural regeneration** - To a limited extent noticed in the blue gum plantations in Nilgiris. In Australia, regeneration succeeded by cutting under growth passing fire over the area and there after giving protection from fire an grazing for the 1st few years.

**Artificial regeneration** – Planting more common than sowing. Coppice areas which have gone through three rotations will roughly be planted in addition to new areas. 3rd and 4th crops (if their yield fall by more than 15” of the potential outturn as read from local yield tables). Preplanting will also be more where blue gum crop is over 40 years. Eucalyptus globlus seed ripen from January or March. The ripe capsules fall to the ground and are collected and dried for four days when they open. The open capsules are then sieved in a basket. The small seeds fall through.

**Nursery treatment** – Vary considerably from place to place and local experience alone should decide the practice. Best time for sowing about February – March and even as early a January for June planting. This enables seedlings of the best size doing obtained for planting early in the beginning of rainy season. Raised beds filled in with a mixture of leaf mound and soil surface is smoothed well and moderately worked. Seed is sown broadcast on the surface and lightly covered with a layer of fine earth. Cover must be given 12” above bed level from the beginning. Shade should be removed during rains as seedlings are very susceptible to drip. Beds should never be flooded. Flat boxes 4 or 5” deep are preferable to seed beds. For new species with little seed, boxes should be adopted normally. Whether raised in beds or in boxes, the seedlings should be pricked out 2” to 3” apart either in nursery or in boxes when seedling attain a height of 2 to 4”. Pricking out requires much care as seedlings are sensitive to any damage to root or stem. May require pricking out on reaching 6” height, preferably this may be done by putting the seedlings in baskets or pots made of stiff paper or bamboo tubes. In the Nilgiris the system of mossing is in vogue, the roots of the seedlings being encased in a ball of earth and wrapped up with mess. This is done when the seedlings are 8” height. This enables retention of moisture. The mossed plants are placed on the ground under

partial shade, regularly watered and shifted every few days to prevent roots fixing in the ground.

**Planting** – Best time in the beginning of rain when seedlings are about 12” – winter planting is more successful than rain planting. Pits dug 2 or 3 months in advance and the soil weathered. In Nilgiris, the area is burnt in April of the year following felling. To ensure good burn removal of slash should be restricted. In low lying or swampy ground, planting in mounds is desirable. Spacing – For blue gum varies from 6’ to 9’ x 9’. 9’ x 9’ is better.

**Subsequent tending** – First one or two years frost protection is necessary for backward plants in hollows by cowls of grass or bracken. This should be done as soon as the N.E. monsoon rains stop and removed in March. Weedings necessary in 1st year. Interfering coppice should be cut back. First thinnings needed in 6th to 11th year.

**System** – Nilgiris and Palnis in Chennai – simple coppice 1 to 15 years rotation. Coppice with standards system was tried but abandoned owing to poor yield (coppice growth on 10 to 15 years rotation for blue gum may range from 100 to 150 tons per acre).

**Questionnaires:**

1. Describe about the cultivation practices of *Acacia auriculiformis*.
2. Write down the cultivation practices of Eucalyptus tree species.