B. Sc. 2nd year, I semester
SFB 406Plantation Silviculture

Visiting Faculty: Padam Bahadur Chand
yaprabha@wlink.com.np

Full Marks: 50 Theory: 40 Practical: 10

Course outline:
General objectives: On completion of this course, students are expected to understand the concepts and practices of plantation silviculture.

Specific objectives: The course specifically will prepare the students to:
1. Understand nursery operation/management techniques, planting as well as reproduction methods
2. Understand the role of silvicultural treatments in forest management
3. Learn the technique of plantation in different types of areas

1. Introduction
- 1.1 Plantation Forests
- 1.2. Methods of artificial regeneration
  - 1.2.1 Regeneration from seed
  - 1.2.2 Regeneration from vegetative parts (sprouting, root suckers and coppice etc.)

2. Nursery operations
- 2.1 Objectives and importance of nursery
- 2.2 Types of nursery
- 2.3 Site selection for nursery
- 2.4 Design and layout of nursery
- 2.5 Nursery construction
- 2.6 Types of nursery beds and their preparation
- 2.7 Methods of seed treatments
- 2.8 Seed testing and seed certifications
- 2.9 Seedling production and management

3. Plantation techniques
- 3.1 Appraisal of planting sites and its protection
- 3.2 Plantation design
- 3.3 Choice of species
- 3.4 Methods of site/ground preparation
- 3.5 Pitting
- 3.6 Spacing
- 3.7 Handling seedlings
- 3.8 Plantation versus direct sowing
- 3.9 Concept of forest fertilization
- 3.10 Concept of irrigation in plantations

4. Silvicultural treatments
- 4.1 Thinning (basis, types, effects of thinning, methods of thinning, regulation of thinning)
- 4.2 Pruning and lopping (type and effects)
- 4.3 Release operations (weeding, cleaning, and liberation cutting, use of herbicides)
- 4.4 Improvement cuttings (T.S.I)
- 4.5 Salvage and sanitation cutting
- 4.6 Prescribed burning and effects of fire on regeneration
- 4.7 Relationship of silvicultural treatments with biodiversity conservation

5. Afforestation/Reforestation on different types of areas

5.1 Objectives and importance of afforestation and reforestation
5.2 Locality factors, choice of species and method of plantation in following areas:
- 5.2.1 Denuded hill slopes
- 5.2.2 Abandoned cultivated lands
- 5.2.3 Grasslands
- 5.2.4 Ravine lands
- 5.2.5 Dry area with or without irrigation
- 5.2.6 Canal banks
- 5.2.7 Road side plantation
- 5.2.8 Farm forestry/on-farm trees
- 5.2.9 Urban forestry

Practical

- Nursery visit, preparation of nursery design and layout
- Study of germination percentage and survival in the lab/nursery
- Planting exercise: digging pits and plantation(Excursion)
- Pruning, lopping and thinning exercise(Excursion)
- Burning and effects of fire on forest regeneration (field visit)
- Visit to demonstration plots to study silvicultural treatments (Excursion)

Readings

- Principle and practice of Silviculture - L.S. Khanna
- Manual of Afforestation, 1994 Vol 1 & 2 - J.K. Jackson
- The practice of Silviculture- D.M. Smith
- Manual on Reforestation techniques- R.C. Ghosh
- Nepal Forestry Handbook - Dr. S.M. Amatya and K.R. Shrestha
- Management of Forest Nurseries, Part III - Adam Harrison
- Forest seed and Nursery Practice in Nepal - Ian Napier and Marcus Robbins
- Thinning Guidelines for *Pinus patula* and *Pinus roxburghii* plantations in Nepal, NACRMLP publication
- Plantation Forestry – R. K. Loona

UNIT I INTRODUCTION

1.1 Plantation Forest

The renewal of a forest crop by natural or artificial means is known as regeneration. Artificial regeneration is also known as plantation. Plantations are done for the production of timber, fuel wood, fodder, fruit and other products for industrial use. Other purposes served by the plantations are minimization of erosion, slope stabilization, protection of water sources and catchments and providing shade and amenity for recreation. Plantations range from those designed to meet the needs of an individual user and to supply the needs of a particular industry. Thus the forests raised through plantations are known as plantation forest.

In Nepalese context, plantations are mainly done by the community forest users group (CFUGs) and government agencies like District Forest Office, District Soil Conservation Office etc. These plantations are supported by various projects like Community Forestry Development Project, Nepal Australia Community Forest Project, Nepal Swiss Community Forest Project, Nepal UK Community Forest Project, Sagarnath Forestry Project, Nepalganj Forestry Project etc.

1.2 Artificial Regeneration

It is defined as the renewal of a forest crop by sowing, planting or other artificial methods. It is carried out for following objectives:

1.2.1 **Reforestation** - Establishing a forest on an area which had forest vegetation before.

1.2.2 **Afforestation** - Establishment of a forest on an area from which forest vegetation has always or long been absent

1.2.1 **Reforestation**: Objects of reforestation are:

- To supplement natural regeneration-When natural regeneration is not coming up to desired level
- To replace natural regeneration-When natural regeneration is slow and uneconomical
- To restock degraded forest-When there are no seed bearers for natural regeneration
- To change the composition of crop-When the proportion of the valuable species is low
- To introduce exotics-When the indigenous species are slow growing.

1.2.1 **Afforestation** - Objectives of the afforestation are:

- Increase in production of industrial timber as well as timber for urban population - There is more demand from industries.
- Increase in production of fuel wood and small timber for agricultural implements and rural housing - Mostly in Terai, people use cow dung for fuel.
- Improvement of Agro-ecosystem - Diversity of agro-ecosystem should be maintained by afforestation in village waste land, common lands etc.
- Moderation of climate and soil conservation in agricultural land - Unused agricultural land and wastelands near it should be afforested.
- Protection of catchment of river - Denuded catchments increase soil erosion and loss of water.
- Increasing natural beauty of the landscape - Bio-aesthetic planting is often done in important public places, road side avenues, canal banks etc.

1.3 Methods of Artificial Regeneration

On this basis of planting material, artificial regeneration is divided into following two types:

1.3.1 **Regeneration from seed** – It is being done by sowing or planting. Seeds are directly sown in plantation area or seedlings are planted to establish plantations.

a. **Sowing**

- Advantages:
  - Cost is less and work is completed soon
  - No nursery is needed
  - Resultant seedling grows without any disturbance
  - No adverse effect on the growth of plant
- Disadvantages:

- Requires large quantity of seeds
- Birds or animals may destroy or eat up the seed sown
- The seedling mortality is heavy
- Weeding is for longer period

b. Planting

- Advantages:
  - The quantity of seed required is much less
  - The damage to seed by birds or animals is eliminated
  - More success percentage
  - Weeding is cheaper

- Disadvantages:
  - It requires more labor and technical knowledge
  - It is costlier than sowing
  - Requires more time
  - Nursery is needed

1.3.1 Regeneration from vegetative part

It involves the reproduction from vegetative part of plants due to their capacity for regeneration. These parts are planted to establish the plantations. This method is useful for those plants which don't produce viable seeds. Following are some of the methods of vegetative propagation:

Sprouting- new part growing on a plant or produce new leaves or buds

Root suckers – roots are severed to produce shoots known as root suckers

Coppice- a shoot arising from the base of woody plant that has been cut near the ground

Cutting – portion of the stem, branch or root is placed in the soil or other medium to develop into plant. Ex. stem cutting, branch cutting, root cutting and root and shoot cutting

Grafting- *scion* of one plant is applied to *stock* (usually rooted) of another plant.

Layering- inducing development of roots on branches while they are attached to trees.

Basic Forestry terms

Growth and Development of a plant - Various stages of growth and development of a plant are designated as follows:

Seedling- Seedling is a plant grown from a seed till it attains a height of about 1 meter, i.e., before it reaches the sapling stage.
Sapling- Sapling is defined as a young tree from the time when it reaches about one meter (3feet) in height till the lower branches begin to fall. A sapling is characterized by the absence of dead bark and its vigorous height growth.
Pole –Pole is defined as a young tree from the time when the lower branches begin to fall off to the time when the rate of height growth begins to slow down and crown expansion becomes marked.
Tree- Tree is the stage of the growth beyond the pole stage when the rate of height growth begins to slow down and crown expansion becomes marked.

Plant Category - Plants may be classified into the following categories:

I) Herb- it is defined a plant whose stem is always green and tender and height is usually not more than one meter.
II) Shrub – it is defined as a woody perennial plant differing from a perennial herb in its persistent and woody stem and less definitely from a tree in its low stature and its habit of branching from the base. A shrub is usually not more than 6 meters in height.
III) Tree- it is defined as large woody perennial plant having a single well defined stem (bole or trunk) and a more or less definite crown. A tree is usually more than 6 meters height, which can, according to species, be up to 127 meters.
IV) Bamboo - It is a perennial grass with woody culms from rhizome.

Tree Classification – Standard tree classification for regular crop is as following:

- **Dominant trees (D):** All trees, which form the upper most leaf canopy and have their leading shoots free.
  a. **Predominant trees –** Comprising of all the tallest trees, general top level
  b. **Co-dominants –** Comprising rest of the dominants falling short of and averaging 5/6 of the average height
- **Dominated trees (d):** Trees which do not form part of the upper most leaf canopy, but the leading shoots of which are not definitely over topped by the neighboring trees. Their height is about ¾ that of the tallest trees.
- **Suppressed trees (s):** Trees, which reach only about ½ to 5/8 of the height of the best trees, with leading shoots, definitely over topped by their neighbors or at least shaded on all sides by them.
- **Dead and moribund trees (m):** This class also includes bent over or badly leaning trees usually of the whip type.
- **Diseased trees (k):** Trees, which are infected with parasites to such an extent that their growth is seriously affected or they are a danger to their neighbors.

Crown cover
Dense canopy – There is strong competition between the crowns of the trees.
Normal canopy – Crowns slightly touch each other.
Light canopy – Crowns don't touch each other but there is not enough space for an additional tree.
Open canopy - There is sufficient space for an additional tree between two crowns.
Gaps– There is enough space for several trees between two crowns.

Regeneration Felling: A felling made with a view to inviting or assisting regeneration. It includes:

- **Seeding Felling –** Opening the canopy of a mature stand to provide conditions for securing regeneration from the seed of trees retained for that purpose.
- **Secondary Felling-** A regeneration felling carried out between the seeding felling and the final felling in order to gradually remove the shelter and admit increasing light to regenerated crop. It is also called intermediate felling.
- **Final Felling –** The removal of the last seed or shelter trees after regeneration has been established. The final stage in the regeneration felling.

Forestry Statistics of Nepal

Total land area = 14,718,100 Ha
Forest area = 4,268,800 Ha
Forest % of total land area = 29
Shrub area = 1,559,200 Ha
Shrub % of total land area = 10.6
Forest and shrub total = 39.6%
Total volume = 387.5 million cu meter
Mean stem volume = 178 cubic meter/Ha (1 cum = 35.3 cft)
Average number of stems/Ha = 408
Main tree species in terms of proportion of total stem volume = Sal (28.2% of total volume)
From 1978/79 to 1994, rate of decrease in forest area = 1.7%

Reference: Forest Resources of Nepal (1987-98). Department of Forest Research and Survey, MFSC Nepal, 1999.

UNIT II NURSERY OPERATIONS

2.1 Forest Nursery

It is an area where plants are raised for eventual planting out (plantation). Plants are produced for fodder, forest, fruit and bioengineering requirements. For artificial regeneration plants have first to be raised under protected condition and then transplanted out in the field to grow into a forest.

2.2 Importance of a forest nursery - Forest nursery is important due to the following reasons:

- Many species do not seed every year. So, seeds are collected in moderate or good seed year and raised in nursery for plantation year after year.
- Slow growing species are grown in nursery and after passing critical stage, they are transplanted. Where as these species are swamped by weeds if directly sown.
- For road side and avenue plantation, tall and sturdy plants are needed which are raised in nursery
- Exotics are best introduced by nursery raised seedlings
- Casualty replacement is done by nursery grown seedlings as sowing done in gaps is liable to failure due to suppression from weeds.

2.3 Types of nursery

2.3.1 Temporary Nursery

- Designed to provide seedlings needed to plant a particular area and when the area is completely planted it will be moved elsewhere.
- There is an opportunity to raise planting stock in the same vegetation zone.
- It is small in size and mostly established in hills for reduction of transport distance, thus minimizing cost and risk of damage.
- Usually established for shorter period of time.
- These nurseries should be within the planting area, or as close to it as possible.
- Establishment cost is less, as permanent structures are not constructed.

2.3.2 Permanent nursery

- It is big in size, centrally located and designed to provide seedlings for many years.
- More investment is needed during establishment
- It is established where there is road accessibility and in plain area.
- Permanent installations like irrigation schemes and specialized buildings are the main feature of this nursery.

2.4 Nursery Site Selection

The selection of an appropriate nursery site is the most important decision affecting the efficient production of good quality plants. The following are some of the technical factors, which need to be considered while siting a nursery.

1. Water supply

- Reliable (understanding with villagers) and adequate water supply is essential.
- Water source should be near and at the higher level than nursery site
- Water should be available through out the year.

2. Availability of suitable soil

For raising seedlings in polythene pot (tube) soil of the actual nursery itself is not important. There should be suitable source of soil preferably forest topsoil and sand within easy reach of the nursery. Following symbiotic organisms should be present in the soil.

a. Mycorrhiza b. Rhizobium

These symbiotic organisms should be present in the soil for the following reasons:

- Most of the trees grow best if their roots are associated with certain symbionts, which help in their nutrition.
- Mostly these organisms are found naturally but in some cases artificial inoculation are needed.

a. Mycorrhiza

- It is a composite structure - neither root nor fungi showing symbiotic relationship.
- Root hairs are be invaded by non- pathogenic soil fungi known as mycorrhiza.

- Absorbs soil moisture by increasing the area of absorbing surface.
- Helps in the absorption of minerals.
- Fixes nitrogen from the raw humus.
- Mostly it is needed for Pine and other species are Deodar, Popplus, Taxus, Salix, Eucalyptus etc.

b. Rhizobium

- Bacteria, which form nodules on the roots of leguminous plants.
- Rhizobium can take nitrogen from the air in the soil and convert into salts that tree can absorb. This process is known as nitrogen fixation.
- Mostly found naturally but some species like Ipip-ipil needs artificial inoculation.
- It is found in Acacia, *Albizzia, Dalbergia, Leucaena* species.

3. Access

Nursery should be near to the plantation site to supply soil and other material and transportation of seedlings and access road should be usable at all seasons of year.

4. Aspect (the direction towards which a slope faces)

Slopes with southerly aspect are much warmer and chosen for hill nursery at high elevation while in low elevation north facing slope is chosen.

5. Slope

- The ideal slope is about 5º, which is steep enough to allow proper drainage.
- Complete flat land should be avoided; it is likely to become water logged during monsoon rains.
- Steeper slopes will have to be terraced and very steep slopes should be avoided, as it may be difficult to make a nursery bed and path on each side to allow access to the beds.

6. Exposure to frost, strong winds and flooding

- At high altitudes, sites, which are particularly liable to frost damage, should be avoided
- Sites exposed to strong winds and with danger of flooding or landslide should be avoided.

7. Labor availability

Labor should be available without difficulty preferably near a village so that they don't have to walk much for work.

8. Availability of land

- There should be enough land to raise the numbers of seedlings needed, and if possible room for expansion.
- Legal enquiries should be made about the legal ownership of the land.

2.5 Nursery layout and construction

Nursery plan should be made before construction of the nursery. In lay out of a nursery, provision will need to be made for:

1. <u>Water supply</u>

- Water is usually fed into the nursery from a stream by a buried pipe or in an open channel.
- Storage tank should be sited at the highest part of the nursery
- Water can be brought down to the beds by gravity, in channels or pipes or by water cans
- In bigger nursery sprinkler irrigation is also used

2. <u>Drainage</u> -

- Drainage system should be constructed to prevent damage from heavy rain
- Terraces should slope very gently inwards and given a slight fall along their length, so that the water flows to the back of the terrace and into drains

3. <u>Beds</u>

- Beds should be 1-1.2 m wide and up to 10m in length. Width of the bed is important for weeding and watering.
- Orientation of bed is from east to west to provide better shade against the mid day sun.

- Seed beds – for sowing seeds
- Stand out beds for seedling in polythene pots (tubes)
- Stump beds for stump cuttings

3.1 Construction of beds

Seed bed –They should be constructed in a well drained area of nursery without shade from nearby trees. Mark the outline of the bed with string tied to sticks at the corner. Along the line of the string, dig a trench 5-10 cm deep and lay flat stones in it on their sides so that they stick out at least 15 cm above the ground; wood, bamboo or bricks can also be used for this seed bed frame. Fill the bottom of bed with a 5 cm layer of gravel, small stones or broken bricks to improve drainage. Cover it with 2-3 cm layer of forest top soil and then fill to within 2 cm of the top of the frame with a 1:1 mixture of sieved sand and forest top soil.

Stand-out beds – These beds are framed with suitable materials preferably stones. After leveling the area for the beds, corners and edges are marked with string and stick. Flat stones can be then set on edge in trenches along these boundary lines to support the beds leaving at least 12 cm protruding above soil level. Split bamboo or poles, bricks or wires can also be used.

Stump beds – These are made on previously cultivated and leveled land aligning the beds with stakes and string. The sides of the bed are lined with stones to prevent soil being eroded.

4. Paths - Proper paths should be made to reach all the beds usually 50-60cm wide

5. Other facilities

- Area for making compost and storing soil with waterproof thatched shelter.
- Store for tools, seeds other materials
- Shade house - Filling pots and other nursery operations

6. Materials and equipment - Checklist of equipment and materials as following:

Expendable materials:

- Seed
- Sand
- Compost
- Polypots
- Heavy gauge polybags for seed storage
- Heavy gauge polythene sheeting
- String
- Seed bed labels
- Mesh wire
- Nails
- Fertilizer
- Fungicide, insecticide
- Nursery, seed, visitor register

Tools and equipments:

- Pate kuto, Chuche kuto
- Hansia
- Shovel
- Kodalo
- Khukri
- Axe
- Doko
- Watering can
- Scissors
- Secateurs
- Flitgun sprayer
- Tin trunks with padlock
- Germination trays
- Soil and sand sieves
- Shade material
- Hammer

7. Fencing – Fencing is barbed wire or stone wall depending upon the availability of fencing material. The barrier must be strong and big enough to keep all large animals out.

2.4 Size of Nursery – It depends on number of planting stock, time in nursery, slope and type of the land. Following things should be considered before calculating the area for the nursery:

- Beds and trays
- Path, irrigation channel
- Working area, soil and sand storage area and shade
- Land for nursery extension for future need

Table 1. Calculation for nursery area with following parameters

Parameters	**3"x7" poly pots for 12,000 plants**	**4"x7" poly pots for 18,000 plants**	**500 bamboo cuttings**	**2000 stumps**
Total plants	15,000 (80% survival)	22,500 (80% survival	833 (60% survival	2,500 (80% survival)
No. of plants/sqm	200	115	4	100
Area in sqm	75	196	208	25
Additional area for > one year	For half of the plants	For half of the plants	All cuttings	All stumps
Additional area for more than 12 months	37.5	98	208	50
Total area for nursery in sqm	112.5	294	416	50

A. Total area =872.5 sqm
B. Total Area (including path and ridges with existing terraces) = A x 1.5 or 872.5 x 1.5 =1308.75 sqm
C. Additional area (for seed beds, storage, shade etc.) = 200 to 300 sqm
D. Grand total = B+C = 1500-1600 sqm (about 3 ropani) area is needed.

2.5 Seed Treatments

The seeds of some species require a specific treatment before germination will commence. While some seeds require treatment to break the seed dormancy, others require it to allow water to penetrate the seed coat. Longer the seed takes to germinate in field, the lesser are the chances of its survival as the growing season after germination is greatly reduced. Germination is prolonged or delayed unless the dormancy is removed. In order to speed up germination of such seeds, they have to be given treatment. Seed treatment is defined as **"various treatments applied to seed prior to sowing in order to the rapidity or completeness of germination**".

There are two main types of dormancy:

a. Seed coat dormancy – It may be physical, chemical or mechanical. In physical dormancy the seed coat is impermeable to water and the seed will not germinate until this impermeability is removed and water can reach the embryo. In chemical dormancy, there are inhibitors in the seed coat which prevent germination. While in mechanical dormancy the seed coat is permeable to water but is so tough that the expansion of the embryo is prevented.
b. Dormancy due to internal factors – Dormancy is caused by the embryo not being fully developed at the time of seed fall; thus a seed needs a period of after-ripening before it will germinate.

2.5.1 Methods of seed treatments – The following are various treatments that hasten germination:

1. **Weathering –** Seeds are exposed to sun, wind and rain to crack its hard coat e.g. teak.
2. **Water treatment** – Seeds are soaked in water to hasten germination with following variations of water treatments:

- Soaking in cold water for one to two days before sowing – This treatment is applied to medium sized dry seeds e.g khote salla.
- Soaking in boiling hot water – Seeds are soaked in boiled water. This treatment is used for hard-coated seeds e.g. albizzia, oak etc.
- Alternate wetting and drying –Seeds are alternately wetted for some hours and then dried e.g. teak.

3. **Passage through animal body** – Some seeds germinate quickly if they are passed through the digestive systems of animals or birds e.g. *Acacia arabica, Santalum album.*
4. **Mechanical treatment –**It refers to the mechanical cutting or filing of the hard impervious coats of seeds so that moisture may reach inside e.g. teak.
5. **Chemical treatment –** Seeds are soaked in various chemical solutions to soften the hard coats e.g. lime water, dilute alkali or acid solutions.
6. **Scorching or fire treatment** – Some seeds are spread on ground on a layer of leaves and given a light burn e.g. teak.
7. **Stratification** – Seeds area spread in layers 1-2 cm deep alternating with layers of sand, peat or charcoal in boxes or baskets stored in pits dug in the ground.
8. **Fermentation** – Seeds are spread on ground covered with grass which is kept moist. Fermentation is induced by adding inoculums from cattle shed or drain.

2.6 Seed Testing – Plantation depends upon the quality of seeds. Therefore, seed testing is essential before use. Seed testing prevents loss in respect of money and effort resulting from failure due to bad seeds and also helps in finding out real cause of failure. It is mainly done to identify the germination capacity and to assess storability and longevity of seed lot.

In Nepal, failure of *Dalbergia sissoo* plantation in private, community and government forest in Terai has been due to the quality of seed which has not been tested before.

2.6.1 Objectives of seed testing

1. **Determination of genuineness –** Identify whether the seed is really of the species which is to be raised before sowing.
2. **Determination of purity** – Most of the seeds are genuine. However, there may be adulteration of some other seeds or foreign matters. Therefore, seeds should be tested for purity.
3. **Determination of seed viability** – For this following tests are carried out:
    - Direct inspection – Representative sample is taken from the seeds to be tested. Each seed is then cut open and seeds which are hollow, insect eaten or bad are excluded. This is also known as cutting test.
    - Physical test – It is done by winnowing or submerging in water and hollow and infertile seeds are separated.
    - Chemical test –Chemicals are used to determine the viability of the seeds. Vital staining test is done as certain dyes have the the ability to stain dead and dying parts of the seeds.
    - Germination test –Seeds are actually induced to germinate and commence growth is called germination test. Germination tests are usually carried out in nursery beds or wooden boxes under some suitable shade. In modern and well equipped laboratories, electrical equipments with automatic controls specially for regulating temperatures are also used.
    - X-ray technique –Seeds are soaked in water for 16 hours and then in a solution of barium chloride for 1-2 hours. While barium chloride penetrates the dead tissues, it can't penetrate the living cells. Seeds are washed and impregnation. The main advantage is that the seeds can be used after the test.

2.6.2 Seed certification – All seeds whether they are dispatched to out side or stored must have certificates giving essential particulars. In India, Forest Research Institute has developed form no. 199 for certification purpose. Seed certification is mainly done to improve the quality of seed to create the sense of responsibility for the collectors.

In Nepalese context, seeds are properly labeled and recorded in the register. Following information should be included in labels:

- Species (Latin name or Nepali name)
- Date of collection
- Place of collection
- Village Development Committee and ward number
- District
- Zone

Additional information useful for the labeling includes the following:

- Altitude
- Aspect
- No. of trees from which the collection was made
- Area from which the seed was collected
- Average size of trees from which the collection was made
- Soil type
- General vegetation type
- Date of planting if from the plantation

2.7 Seedling production and management – Nursery operation plan is prepared for the production of planting stock and nursery management. Following things should be considered in the plan:

- Type of resources needed
- Infrastructures like wall, buildings, water supplies etc.
- Tools and equipments
- Expendable materials including seeds
- Labors
- Time

2.7.1 The timing seed collection and sowing –Availability of seed is fixed by the collecting season in relation to time needed to grow a particular species in the nursery. Example of timing is given in the following table 1:

Table 1. Timing of seed collection and sowing

Species	**Collecting season**	**Sowing**	**Months in nursery**
Uttis	Nov-March	August	11
Khote salla	Jan-March	August	11
Lapsi	Oct-January	February	5

2.7.2 Planning seed supplies- The quantity of seed required must be calculated, the sources identified, arrangements made for collection and the cost estimated. See table 2 below for planning plant production.

Table 2. Planning plant production

SN	Particulars	Uttis	Khote salla
1	Number of plants needed	5,000	5,000
2	Number of plants to be produced	6,250	6,250
3	Number of seeds needed	25,000	25,000
4	Seeds per kg	1,000,000	10,000
5	Seed type	Orthodox	Orthodox
6	Transplant or direct sowing	Transplant	Transplant
7	Size of pot (inch)	3x7	3x7

2.7.3 Supplies of other materials –Information recorded in table 2 will be used to calculate the quantities of polypots, soil, sand and compost that will be required. For example, 19.5 kgs poly pots of 3"x7"size will be required for 12,500 seedlings.

2.7.4 Calendar of operation – Calendar of operation is prepared to carry out nursery operation activities in logical way. Following example shows the calendar of operation for *Chuletro.*

Month	**Activities**
December-January	Order polypots and other materials
February-May	Explore seed availability and arrange for collection, collect soil and sand
April-May	Prepare potting mixture and fill pots
May	Collect materials for mulch
June	Clean and sow seed
July-August	Remove mulch, transplant
July-September	Collect vegetation for compost making
August-October	General maintenance, weeding
November	Shade preparation for frost protection
November-February	Erecting shade in evening and removing in morning
March	Root pruning
April-May	Prepare shades for hail
June-July	Prepare seedlings for transplant

2.7.5 Record Keeping –Keeping good nursery records is most important. Nursery register is maintained with following information:

- Species
- Seed source
- Sowing date and bed number
- Seed treatment
- Quantity of seed sown or number of seeds
- Date of germination
- Number of plants pricked out from bed to bags
- Germination percent
- Date pricked out and bed number
- Number of full sized seedlings produced
- Other descriptions (watering, shading, insect control etc.)

2.7.6 Type of planting stock

1. Containers raised plants (plants in polythene pots)
   - Growth within the cylinder of soil is continuous, so shock is avoided
   - Risk of failure is reduced when conditions are unfavorable
   - Roots do not dry out during transportation
   - Nursery not needed to be sited where there is good soil
   - Difficulty in transportation and costly

2. Bare root plants
   - Much easier to transport in plantation site
   - Less costly for production and transportation
   - Survival of bare root plants is low

3. Large ball rooted seedlings wrapped in grass, sacks
   - More than 15 months older in nursery
   - Lifted with a ball of soil and wrapped in grass or sack
   - It is more time consuming and costly in transportation
   - No browsing and more survival

4. Stumps (root and shoot cuttings)
    - Cutting off the stems a few centimeter above ground level and shortening and trimming the roots
    - Easier to transport
    - Only be used for a limited range of species like Sissoo and Teak

5. Cutting and vegetatively propagated materials
    - It is done when difficult to raise from seed or seed is not readily available
    - Genetically identical trees can be produced
    - Reduce the time needed in nursery to obtain plants large enough for planting in the field
    - Mainly used for *Salix* and *Populus*

2.7.7 Types of Container

- Polythene pot are mostly used in Nepal
- 3"x7" in size lay-flat, closed at the bottom and made of 200 gauge polythene. Number of polythene pots per kg are 640.
- There are eight 5 mm holes punched at the bottom part for drainage and aeration
- Volume is 300 ml and contains 300 g soil
- These are transparent or black
- For fodder species, bigger size polythene pots of 4"x7" are used which contain about double soil than 3"x7" pot. Number of polythene pots per kg are 510.

2.7.8 Potting mixture - The ideal potting mixture should be:

- Light in weight
- Fertile - retaining nutrients well
- Well drained but retaining sufficient water
- Sufficiently cohesive so that the root ball remains intact after the polypot is removed
- Easily obtainable

The forest topsoil may be satisfactory as a potting mixture without further treatment, but in Nepalese context, most soils are too heavy and need the addition of sand or compost. Proportion of different ingredients in potting mixture is as follows:

- For slightly infertile soil with too much clay - Topsoil : sand : compost = 3:1:1
- For soils that are too sandy - Topsoil : sand : compost = 3:0:1
- For soils with slightly too much clay - Topsoil : sand : compost = 3:1:0

2.7.9 Germination and Pricking out

2.7.9.1 The process of germination

- Germination is the development of embryo and its emergence from seed.
- It starts with the absorption of water through seed coat which bursts open after swelling. Then physiological process begins using stored food and radicle and plumule emerge from the seed.
- The seed must have water, oxygen and proper temperature.
- It is complete when the roots can absorb moisture and nutrients from soil and leaves can photosynthesize carbohydrates.
- There are two types of germination: epigeal and hypogeal

Sowing seed directly into pots

- Seed may be sown directly into the pots usually when the seeds are large in size.
- For seeds which are large enough to be handled individually and which usually have more than 40 percentage germination like, Chiuri, Koiralo, Badhar, Tanki, pine etc
- Labor needed for pricking out is saved and the damage to the tender young seedling is avoided
- If seeds are very small, several seeds are needed to be sown. It is wastage of seeds.

Sowing into seed beds or seed trays

- Either trays or beds can be used for raising seedlings which are later to be pricked out into containers

- Trays are portable so germination can take place protected from the rain under the roof of a shed.
- Trays are made of wood or plastic or metal
- Seed beds are made with a good frame and should be constructed 1-1.2 m wide and 15-20 cm high
- The bottom of bed is filled with 5 cm thick layer of gravel or small stones to provide drainage. This is covered with a layer of forest top soil 2-3 cm thick and remainder filled with top soil and sand at 1:1 ratio. The top 2cm should be left unfilled to prevent from washing by rain.
- Seeds beds are used for Lapsi, Bakaino, Lankuri, Champ, Painyu etc

2.7.9.2 Pricking out

- This is very delicate operation and is done shortly after germination
- The best time is when the seedlings have produced one to two pairs of true leaves in addition to the cotyledons
- Delay in pricking out may damage root
- It is usually done in cloudy day or late afternoon or evening

Sequence of operation

- One day before, thoroughly water the polypots in which the seedlings will be pricked out
- Immediately before starting, seed beds or trays are lightly watered
- The seedlings are lifted carefully by flat piece of stick to lever out seedlings and soil
- The seedlings are held by leaves as holding by stems will damage to tender stem tissues
- These seedlings are kept in a dish of water
- To prick out the seedling, a hole is made using a pointed stick. It should be deep and wide enough to contain seedling
- The hole is then filled with 1:1 mixture of sieved soil and sand and closed by inserting stick around it.
- Seedlings are watered lightly and these are kept under shade.
- When the seedlings start to produce new leaves, shade is removed.

UNIT III PLANTATION TECHNIQUES

3.1 Appraisal of planting sites and its protection

Plantations are done for the production of fuel wood, fodder, timber and supply raw materials to the industries. Besides this, plantations are also established to minimize erosion on slopes, around water sources and reservoirs.

3.1.1 Works to be done in plantation area – Following activities are carried out:

Time table – This is prepared for works to be done outside the plantation area as well as inside the plantation area. This time table has to be prepared by working backwards from the crucial time of sowing and planting.

Boundary demarcation - It is the first work to be done. Area of plantation is selected and then the boundary of the plantation demarcated.

Marking and felling – After demarcating the area, its stock map is prepared. Then the trees standing in the area are marked and felled.

Soil and planting map –After surveying and mapping the outer boundary, the area should be surveyed in detail to make a soil map showing different types of soil which will help to decide type of species to be raised. Thus, soil and planting map showing the method of soil working, alignment of ridges or trenches, the species to be shown or planted in various parts should be made.

Inspection paths –After making soil and planting map area is divided into blocks based on the area of the plantation. These blocks are separated by roads or paths. A path or motorable road should be left on the outer periphery of plantation.

Staking out –Position of lines and pits are clearly marked on ground by fixing wooden or bamboo pegs for equal distribution of the plants in regular pattern.

Soil preparation – Digging of soil at places where sowing or planting is to be done either manual labor or tractor ploughing. Main objectives of doing this are:

- To enable seedling or cutting to develop long tap root easily
- To enable rain water to penetrate deeper so that moisture is retained in soil for a longer time
- To improve aeration of soil
- To dig out roots of weeds so that weed growth is reduced

3.1.2 Protection of plantations

Fencing – Fencing is done to protect the plantation from different damaging agencies. Following are the commonly used fences:

a. **Cattle proof barbed wire fence –**It is composed of 4 or 5 strands of barbed wire with fence posts.

b. **Game proof fence** –It is erected to keep away wild animals and consists of woven wire at the bottom with 5 or 6 strands of barbed wire on top.

c. **Special wild boar and porcupine proof fence** –Thicker woven wire has been used and buried 30 cm in the ground. There are 5 or 6 strands of barbed wire above the ground and one strand of barbed wire is also put up at the bottom inside the ground.

d. **Stone fence** – Where stones are available and wooden fence posts are expensive, stone wall fences are constructed.

Social fencing – Local communities protect their plantation area by not allowing their cattle to graze and protecting the area by guarding themselves on rotational basis or by hiring watchers.

3.2 Plantation design

Pattern of planting

Following patterns of planting are generally used:

1. Line planting - Plants are planted at some spacing in lines which are also at some distance forming a rectangle.

No. of plants per ha = $\frac{100 \times 100}{}$

distance of plants in line x distance between the lines

2. Square planting - Plants are planted in square patterns.

No. of plants/ha = 100x100
Square of the planting distance

3. Triangular planting - Plants are planted in the pattern of equilateral patterns.

No. of plants/ha = 100x100X1.555
square of planting distance (i.e. side of the triangle)

4. Quincunx planting - An extra plant is planted in the center of each square of four plants.

No. of plants/ha = 2x100x100
square of the side of the planting square

3.3.1 Choice of species -It depends upon:

- Climatic conditions - Only those species which can grow in the regional climate as well as in the microclimate of the plantation site should be selected.
- Soil Condition - Only the species which are suited to soil and moisture conditions should be selected to avoid failure. Plantation should be decided on the basis of stock map prepared before felling.
  Indicator plant (soil indicator) - Any plant which by its presence indicates the quality of the site. Ex,
  Lime rich soil - *Cupressus torulosa*
  Soils with high concentration of soluble salts - *Acacia arabica*
- Stage of Succession - The stage of succession which the soil has reached should also be noted to decide the species which can grow in it.
- Objects of Management - Choice of species is also affected by the object of the plantation.
- Specific Market requirements - Change in taste of consumer and market requirements should be considered while selecting species for plantation.
- Growth rate - The choice of species is also affected by the growth rate as present trend is to raise fast growing species.
  A fast growing species - Height increment of 60cm/annum, minimum yield of 10cum/ha/year in a short rotation of 10-15 years.
- Availability of suitable exotic - If indigenous species can't meet the fast growing requirement of industrial timber, exotic species should be selected based on suitability of local conditions.
- Ease of Establishment - The ease with which a species can be raised also affects the choice of species.
- Cost - The cost of raising a species also affects the choice.
- Effect on Site - If a species reduces productive capacity of site, it should not be selected.

3.3.2 Mixture in Plantation

While making a choice about species, it should also be decided whether they will be raised pure or mixed with following considerations:

- Soil deterioration - Pure crops, particularly when they are light demanding species deteriorate soil and decrease its productivity.
- Resistances to diseases - Pure crops are often destroyed by insects, plant parasites or fungi. Mixed crops exhibit high degree of resistance.
- Damage by wild animals - Raising of pure or mixed crops should be taken after considering the incidence of animal population.
- Increment and total yield - When a valuable species is raised pure, its increment is not affected by any other species as in mixed plantation.

- Difficulty in execution of silvicultural operations - When the species with different silvicultural requirements are mixed in a plantation, they present difficulty in execution of silvicultural treatments.

Kinds of Mixture - Mixtures are of two types:

a. Temporary mixture - Secondary species are mixed with main species only for a part of the rotation. It is raised with following objects:

- Providing protection against adverse factors - To afford protection against browsing or frost, main species is mixed with temporary species.
- Providing competition in the early stages to obtain better bole form - When the main species is likely to become branchy, it is mixed with other species in order to help it to develop good bole form.
- Providing cover to the ground and suppression of weeds - When the main species is sown at wide spacing, some other species is sown in between to afford protection to the soil as well as for suppression of weeds.

b. Permanent mixture - The mixed species remains with the main species through out the rotation of the crop. These are of two types:

- Horizontal or even-aged mixture - Both the species form the top canopy. Ex. Khair and Sissoo
- Vertical or uneven-aged or storeyed mixture - Main species is in the top canopy while the accessory species is in the middle canopy. Ex. Sissoo and mulberry

3.3.3 Arrangement of staff and labor

Both skilled and semi-skilled staff and labor is needed for artificial regeneration. Arrangement of labor may be made by the following means:

- Labor on daily wages - Skilled and semi-skilled labor is employed on daily wages.
- Work through contractors - Contract is given for fencing, bush cutting, pitting and soil preparation works.
- Labor having permission to raise agricultural crops in the plantation area - Labors are permitted to raise agricultural crops in lieu of wages for the work.

Taungya system - The plantations in which forest crops are raised along with agricultural crops is called Taungya system.

- First evolved in Mynamar in 1850's for replanting vast teak areas.
- Taungya (Taung - hill and ya - cultivation) is Burmese word
- Modified form of shifting cultivation
- Labors are allowed to raise crops along with forest plantation
- After 4-5 years, they move to another patch of land

Types of Taungya system -There are three types of Taungya system:

1. Departmental Taungya - Forest Department gets agricultural crops and employ labors for plantation work to keep down weed growth
2. Leased Taungya - Land is leased for raising agricultural crops along with plantation
3. Village Taungya - It is done by villagers settled down in the village inside the forests.

Advantages:

- It is cheaper method of artificial regeneration
- Labor problem is solved and provide work to the landless labors
- It utilizes the site fully and contribute in the food production

Disadvantages:

- Loss of soil fertility and exposure of the soil
- Increase the possibility of erosion due to ploughing
- Increase the danger of epidemics
- Legal complications are created

- A kind of human exploitation.

3.4.1 Site/ground preparation

Site preparation

- It is done to eliminate the existing vegetation on the site, wholly or in part in order to reduce competition to the planted trees and to provide access for planting.
- The method and intensity of site preparation depends on the nature of the existing vegetation, the plantation techniques and species to be planted and on economic factors.

3.4.2 Method of site preparation

Manual site preparation

- Use of labor to clear site is common method used in Nepal
- Fire is also used for clearing the site. For this fire lines should be made around the plantation area.

Mechanical site preparation

- It is done for establishing large areas of commercial plantations.
- The trees are pushed down by bulldozers and site is cleared by tractors.

Site preparation on difficult sites

- On very steep or eroded sites special method of land preparation may be needed to prevent further erosion and to direct run off to the places where it is needed and will do least damage.
- The methods are –terracing, contour furrowing, contour ridging and trenching etc.

3.4 Pitting – Planting in pits prepared well in advance planting is a common practice in South Asia but it is relatively unusual in other parts of the world where it is more customary to make holes just large enough to take the seedlings at or just before the plantation. Roots of the seedlings will be in contact with already worked loose soil and there will be no weeds around the seedling.

- Pitting should be done while the ground still has some moisture in it. Fairly soon after monsoon is the good time but may be done until November and December.
- The standard pit in Nepal is a circular at least 30 cm deep and 30 cm diameter at the bottom.
- After digging the pit, it should be checked whether all the soil has been removed. Then soil should be replaced in the pit removing the grasses.

3.5 Spacing - It is the distance between the plants put out in a plantation or standing in a crop. When the distance between plants is small, it is called **close spacing** and when the distance is large, it is known as **wide spacing**.

Table 5. Difference between close and wide spacing

Close spacing	Wide spacing
Advantages: ▪ Canopy closes soon and it checks growth of grass and weeds ▪ As no. of plants are more thinning becomes easier ▪ Natural pruning makes the bole cleaner	▪ Saving of seeds and plants ▪ Cost is less ▪ Less no. of labor is required
Disadvantages: ▪ Requires large quantity of seeds or plants ▪ Cost is more and more labor required	▪ Canopy takes long time to close ▪ Trees tend to become branchy resulting in knotty timber ▪ Thinning becomes difficult

The spacing varies with species and in the same species with the local conditions. The following factors govern the spacing:

- Rate of growth of species - Fast growing species have wider spacing and slow growing species have closer spacing. Important objective is early canopy closure so that soil may not deteriorate due to exposure.
- Habit of branching - Large no. of branches arising from the stem, reduce the timber volume and decrease its value. Trees producing large braches need close spacing so that due to deficient light natural pruning may make the bole clear.

- Number of annual rings - Plants are raised at wider spacing for lesser number of rings per centimeter, e.g. paper, pulp, match etc. as it requires rapid diameter increment. If denser wood is required, close spacing is adopted as there will be more annual rings per centimeter.
- Height of planting material - For tall plants, wider spacing is needed and for small planting stock, the spacing should be closer .
- Site factor - Close spacing is adopted in drier areas and where there is a danger of weed infestation.
- Inter-cultivation - Wide spacing is required for it as there are agricultural crops grown in between.
- Market for small sized timber - Close spacing is adopted if there is market for thinned material.
- Fruit production as objective - Wider spacing should be adopted.
- Cost - Close spacing is less costly than wider spacing. So, availability of the fund has a great influence on the spacing to be adopted.

In Nepalese context, standard spacing in plantation is 2.5m x 2.5m with 1,600 plants per hectare.

3.6 Handling seedlings

Preparing plants for planting out

Hardening-off

During plantation, seedlings will be exposed to much more difficult conditions, and if the transition from nursery to plantation conditions is too abrupt, the seedling may suffer. To make this transition a gradual process known as hardening off is used. Plants are accustomed to and able to tolerate difficult conditions due to hardening off. Its main features are:

- Removal of shade (at an early stage)
- Spacing
- Root pruning
- Reduction of watering
- Discontinuing the use of fertilizers

Culling

Seedlings are sorted according to their suitability for planting. Weak, undersized, over grown and badly formed plants should be culled and thrown away. Seedlings suitable for plantation should be:

- 20-30 cm in height
- have straight, undamaged, un-forked stems
- be of a healthy, deep green color
- have a root collar diameter of over 4 mm.
- free of insects or fungal diseases

Packing for transport

Plants in poly pots -Plants in polypots should be well watered two or three days before they are to be transplanted to the field and lightly watered the evening before. They should not be watered heavily immediately on the day of transport. Plants should be handled by the container, not by the shoots. They are transported by dokos or wheeled transport with trays.

Stumps – Stumps are wrapped in wet jute cloth and tied in bundles with string and kept in cool shady place.

Bare root plants – These are dug up carefully and, the soil shaken off their roots and culled and then made up into bundles with root wrapped in jute cloth.

3.7 Plantation versus direct sowing

There are two methods of artificial regeneration - sowing or planting

a. Sowing

- Advantages:
  - Cost is less and work is completed soon
  - No nursery is needed
  - Resultant seedling grows without any disturbance
  - No adverse effect on the growth of plant
- Disadvantages:

- Requires large quantity of seeds
- Birds or animals may destroy or eat up the seed sown
- The seedling mortality is heavy
- Weeding is for longer period

b. Planting

- Advantages:
  - The quantity of seed required is much less
  - The damage to seed by birds or animals is eliminated
  - More success percentage
  - Weeding is cheaper

- Disadvantages:
  - It requires more labor and technical knowledge
  - It is costlier than sowing
  - Requires more time
  - Nursery is needed

The choice between the two methods of artificial regeneration depends upon:

- Species to be raised - Most of the species can be raised by both methods but some by sowing or planting only.
- Condition of the site - In poorer and difficult sites, infested with grasses sowing is generally not successful
- Availability of seed - Species which don't produce large quantities of seed every year have to be raised by planting
- Cost - Lesser cost with greater success is preferred.

3.8 Concept of forest fertilization

Forest fertilization

- Application of fertilizers in the plantation is known as fertilization which is done for quick and best return. However, fertilizers have not been used in forest plantations so far to any significant extent.
- Few forest soils provide an optimum supply of the nutrients essential for the growth of the trees. The nutrient elements most likely to be deficient are the NPK.
- In order to apply fertilizers to the best advantage, requirement of each species and the fertility status of soil in which they are to be raised will have to be determined.
- Tree seedlings exhaust the soil more rapidly than many agricultural crops. Therefore, fertility can be maintained only by proper application both organic and inorganic fertilizers.

3.9 Concept of irrigation in plantation

Except for seed orchard, nurseries and other sites of very intensive tree culture, there is little use of irrigation in forestry as irrigation water is usually more valuable for agricultural use. There are a few places in the world where hybrid poplars and other species of alluvial flood plains are grown with supplemental irrigation water. The most common ways of increasing the water supply of forest trees are the various methods of reshaping the ground surface to concentrate surface run off water on the roots of planted trees.

As watering a plantation is both difficult and expensive, it is usually not done but following are some exceptions to the general rule:

- Dry tracts where irrigation is easily available as irrigation become necessary for the establishment of seedlings
- Road side avenue plantation, plants are watered during 1st and 2nd year to accelerate their growth.
- Irrigation of *Casuarina* plantation in coastal sand is done to help the seedlings to send their roots through the non retentive sand to the water table as early as possible.

UNIT IV SILVICULTURAL TREATMENTS

4.1 Tending Operations

Tending is defined as "an operation carried out for the benefit of a forest crop, at any stage of its life between the seedling and the mature stages; it essentially covers operations both on the crop itself and on the competing vegetation, e.g., weeding, cleaning, thinning, pruning and climber cutting."

Intermediate cuttings that are aimed primarily at controlling the growth of stand by adjusting stand density are called **thinnings**. Treatments to regulate species composition and improve the quality of very young stands are **release operations (weeding, cleaning)**, cuttings made in older stands for these purposes are improvement cuttings; those that involve only the branches are **pruning**.

Release operations free young stands of desirable trees, not past the sapling stage, from the competition of undesirable trees that threaten to suppress them. The pesticides used for killing the woody weeds of the forest are called **herbicides** because of their wider use against the herbaceous weeds.

4.2 Silvicultural operations

A. WEEDING

- In all regeneration areas, whether natural or artificial, the individuals of the unwanted species appear much earlier than those of the desired species and, if not kept in check, they smother and ultimately kill the latter.
- Any unwanted plant that interferes or tends to interfere with the growth of the individuals of favored species' is called weed. Therefore removal of
- A tending operation done in the seedling stage in nursery or in a forest crop, that involves the removal or cutting back of all weeds.

Objects of weeding

(i) To reduce root competition and transpirational water loss- Weeding is done primarily to reduce root competition for moisture and nutrients and also to reduce water loss by transpiration.

(ii) To improve light conditions- Weeds affect the light reaching the seedlings on the forest floor and tall dense weeds may cut it out completely. In order to ensure proper growth and survival of seedlings, weeding have to be done regularly.

Season, number and duration of weeding

- As a general rule, weeding must be done before (i) weeds have started suppressing the seedlings and (ii) the seedlings have stopped growing.
- After the growth period is over, the seedlings require protection against frost and browsing, so weeding should not be done.
- Thus, in practice, weeding are done in plantations during the rains and stopped by the end of September
- The number of weeding to be done in a particular year depends upon the intensity of weed growth and the rate of growth of seedlings of the favored species.
- The duration for which weeding should be done also varies with species, the rate of growth, intensity of weeds and local conditions. Generally it is done for 3 years but for fast growing species it may require for 1 or 2 years only.

B. CLEANING

Cleaning is defined as **'a tending operation done in a sapling crop, involving the removal or topping of inferior growth including individuals of favoured species, climbers, etc., when they are interfering with the better grown individuals of the favored species'.**

Object of cleaning

(i) To improve light conditions- Cleanings are carried out primarily to improve light conditions as the amount of light required by a growing sapling to carry on its vital life processes is far more than that by a seedling.

(ii) **To reduce root competition -** Cleanings reduce root competition, thereby enabling saplings to develop faster and better.

(iii) **To reduce transpirational water loss-** Removal of excess foliage from each unit area in cleanings also reduces the transpirational water loss from the soil.

Season, frequency and duration of cleanings

- To give maximum benefit, cleanings should, be done during the season, which is the growth period of the favored species and in which the undesirable species interfere most with their growth.
- Therefore, cleanings should be done during the rains but where this is not possible, they may be done during summer and winters.
- If the saplings are dense and grow faster, cleanings are done every year; otherwise they are done at an interval of some years.
- Cleanings are normally carried out through out the sapling stage of the favoured species in order to help them to develop into straight and well-grown poles.
- The following operations are usually done in cleanings:

  Cutting back shrubs and associated herbs which tend to interfere with the growth of saplings of the desired species
  Cutting back of the malformed or diseased individuals of the desired species;
  Singling of coppice shoots of the favoured species; and
  Climber cutting.

C. 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'.

Objects of thinning - Thinning is done in crops with following objects:

1. **To distribute growth potential of a site amongst the trees retained**

- Thinning is done to regulate an even distribution of the growing space for the purpose of improving the growth and form of trees that are left.
- Thus, thinning results in the production of an optimum number of big-sized trees of good form and quality.

2. **To increase the net yield of timber and money from a stand**

- The increase in the net yield of timber results in increased financial yield not only because of increased volume but also because of higher rate obtained for bigger sized and relatively better quality timber from trees of larger sizes and good form.

3. **To obtain earlier returns from capital invested in a stand**

- **Utilizing of thinned material-** As thinnings are started from the time the crop passes into pole stage, all the trees that would have perished in natural selection are removed in thinnings and utilized.
- **Shortening of the rotation-** As the reduction in number of trees in thinnings, increases the diameter of the remaining trees, a given exploitable diameter can be reached in shorter period by heavier grades of thinnings.

4. **To produce a different smaller size of timber which can meet a different object of management**

- Poles and smaller-sized trees produced during thinnings cater to a different market e.g.; for transmission poles in case of Sal and some other species.
- Some times, this produce is almost as much or even more valuable than the main crop.

5. To maintain hygienic conditions in the stand

- The thinnings remove the diseased as well as dead or dying trees, which are liable to insect, attack and thus ensure the production of disease-free healthy stand.
- They also reduce the fire hazard by removing the suppressed trees along with the dead and dying trees. Thus the losses due to attack by injurious insects, fungi as well as by the fire are considerably reduced.

6. To obtain timber of the desired quality and mechanical strength

- Thinning improve the quality of wood produced from a stand removing trees of poor quality in favor of best trees.

7. To ensure decomposition of raw humus

- As thinning open up the crop, they increase the light and temperature on the forest floor which assist in decomposition of raw humus and consequently in increasing the fertility of the soil as well as in helping natural regeneration to establish.

Types of Thinning

Thinning vary with the nature of the crop, i.e., the methods of thinning used in regular crops are different from that used in irregular crops.

Types of thinning used in regular crops

1. Mechanical thinning
2. Ordinary thinning
3. Crown thinning
4. Free thinning
5. Maximum thinning
6. Advance thinning

1. MECHANICAL THINNING

Mechanical thinning is defined as 'a thinning in which the trees to be cut are selected by some rule-of-thumb, e.g., trees in alternate diagonals or rows, alternate trees in alternate rows or every second, third, fourth, etc., line or minimum spacing gauged by a standard stick (Stick thinning).

- This thinning is carried out in early stages of the crops when the canopy differentiation has not taken place
- It is done by retaining trees at predetermined spacing or thinning pattern with practically no regard to the potentialities of the growth of the trees.
- This thinning can be carried out only in those plantations or natural regeneration areas where the plants are uniformly spaced and have nearly uniform growth; elsewhere it is difficult to carryout.
- Even in this thinning, the diseased, damaged and definitely badly shaped plants are always removed, even though their removal may affect the predetermined standard spacing.
- This thinning is carried out either by some rule of thumb or with the help of a stick of prescribed length or may be according to some **formula** based on the studies of various natural crops.

For *Cedrus deodara*: D = d (Glover's formula).
For *Shorea robusta*: D = 1.5 d (Warren's formula).
For *Dalbergia sissoo*: D = 2d (Howard's formula).
For Teactona grandis; D = 1.5 (d+4) (Sagreiya's formula).

In the above formula **D** stands for the spacing of trees in feet and **d** for average diameter of trees in inches.

- When mechanical thinning is done with the help of a stick of prescribed length, it is called **stick thinning**. In this thinning when a stick of prescribed length cannot be passed horizontally between two plants, one of them is cut down unless there are specific reasons for retaining both. The length of the sticks depends upon the average diameter of the crop and the species.

For *Shorea robusta*, length of stick is 0.90 m for average diameter from 2.5 to 6.25 cm and stick length is 1.20 m for average diameter from 6.25 to 10cm.

For *Cedrus deodara*, length of stick is 2.40 m for average diameter of 20 cm.

Application

- In natural crop of Deodar, the first mechanical thinning is done along with cleaning and the plants are spaced at 1.2m x 1.2m when they are 1.8m high. The 2nd mechanical thinning is done when the crop has average diameter of 20 cm and plants are spaced at 2.4m x 2.4m.
- In Teak plantations raised at a spacing of 1.8m x 1.8m, the first mechanical thinning is done when the crop attains a height of 7.5 to 9m. After 5 years, another mechanical thinning is done in which alternative rows are removed reducing the number of plants again by 50% and leaving the spacing about 3.6 x 3.6m.

2. ORDINARY THINNING

- The development status of the trees and their position within the crown canopy structures are the bases for choice.
- The felling starts from the lower most canopy or crown classes and progresses gradually to higher canopy or crown classes, it is called **'low thinning'** or '**German thinning'** or **'thinning from below';** however, now the more commonly used term for such thinning is '**Ordinary thinning**'.

- It is defined as **'the method of thinning in common use that consists in the removal of inferior individuals of a crop, starting from the suppressed class, then taking the dominated class and lastly some of the dominants'.**
- The basic principle underlying ordinary thinning is that the trees, which have wholly or partly lost in the social struggle, should be removed because while they have no future, they adversely affect the growth of dominant trees by root competition.
- In other words, ordinary thinning follows nature, which gradually reduces the number of trees in a stand by removing the trees of the lower canopies.

Grades of ordinary thinning- In order to prescribe which classes of trees are to be removed in a particular thinning in a crop, it is necessary to differentiate various thinning grades. A thinning grade **'refers to the relative extent to which a crop is opened up in thinning'.** Using the class symbols for the classes of trees to be removed, the following thinning grades are recognized:

1. **Light Thinning (A grade):** This grade of thinning is limited to the removal of dead, dying, diseased and suppressed trees.
2. **Moderate Thinning (B grade):** This grade of thinning is limited to the removal of dead, dying, diseased, suppressed, defective dominated, whips and occasional very defective dominant.
3. **Heavy Thinning (C grade):** In addition to the removal of all classes of trees of B grade, this grade consists in the removal of remaining dominated and such of the defective co-dominants as can be removed without making lasting gaps in the canopy.
4. **Very Heavy Thinning (D grade):** This grade consists in the removal of all tree classes to be removed in C grade as well as some of the good dominants, subject to the condition of not making any permanent gap in the canopy.
5. **Extremely Heavy Thinning (E grade):** This is about the heaviest thinning that can be done in a crop without making permanent gaps in the canopy. In this grade more of the good dominants are removed as compared to D grade.

Application

- It is applied in case of light demander species such as, Pine, Teak, Sissoo
- It is suitable for areas where there is market for small sized timber
- Area where there is no danger of soil deterioration as a result of removal of suppressed and dominated trees.

Advantages

- It is useful in areas where the demand of small timber is more and have market for selling
- It is simple to apply
- It improves the hygienic condition because several diseased and insect infected trees are removed
- Removal of lower crown classes help in the natural regeneration of the species

Disadvantage

- This thinning is carried out after the trees have remained in competition for a long time to develop crown differentiation. Due to this dominants have already suffered from the adverse effect of competition.
- In absence of the demand or market of small thinning poles, the thinning material can not be utilized economically. If retained in the forest, it would increase the fire hazards.
- The removal of the suppressed and dominated trees exposes the soil and often results in the deterioration of the site.

3. CROWN THINNING

- The development status of the trees and their position within the crown canopy structures are the bases for choice.
- As most of the trees removed in this thinning, are from the upper crown classes, it is called crown thinning.
- It is defined as **' a method in which thinning is primarily directed to the dominant trees in a regular crop, the less promising ones being removed in the interest of the best available**

individuals; the dominated and suppressed stems are retained unless they are dead, dying or diseased'.

- It is also called **"French Thinning'** because of its origin in France, **'thinning from above'** and **'high thinning'** to differentiate it from the corresponding names of ordinary thinning.

Grades of crown thinning: The following two grades are recognized:

i. Light crown thinning - This consists in the removal of dead, dying and diseased trees and some dominants so as to make enough space available for the best growing individuals.

ii. Heavy crown thinning - In this grade, selected best stems are retained only.

Application

- It is applied in case of moderately shade tolerant species, such as Deodar, Sal etc.
- It is suitable for areas where there is demand for only relatively big-sized timber
- It is also suitable for areas where there may be danger of frost, snow, drought and wind damage so that if any dominant tree dies, its place can be filled by trees from the lower canopy.
- It is particularly suitable for drier areas where there may be danger of site deterioration

Advantage

- As a result of space given to the retained dominant trees, they grow faster in crown thinning
- The suppressed and dominated trees which are not removed , keep the weeds and shrub growth under control
- The presence of suppressed and dominated trees in the stand results in the natural pruning of the retained dominant trees and production of knot-free big sized timber
- The suppressed and dominated trees protect the soil from deterioration.

Disadvantage

- The suppressed and dominated trees may affect the growth of the dominant trees by root competition
- The suppressed and dominated trees present obstacle in felling of trees during thinning
- Viewing from below, identification of trees for removal and retention presents difficulties and it needs greater skill.

Difference between Ordinary and Crown thinning

Crown Thinning	Ordinary Thinning
The class from which maximum trees are removed is the dominant class	Maximum trees are removed from the suppressed class.
Most of the suppressed and dominated trees are retained unless they are dead, dying or diseased	Most of the suppressed and dominated trees are removed and only some are retained.
It is suitable for areas where there is demand for only relatively big sized timber.	It is useful in areas where small-sized timber obtained from the suppressed and dominated trees is saleable.
The immediate cash return is greater than ordinary thinning because the material removed is larger and of greater utility	The immediate cash return is lesser than crown thinning because smaller trees are removed

4. FREE THINNING

It is defined as a method of thinning in which attention is concentrated on evenly spaced selected stems which are retained until maturity or till the last thinning or two, thinning being directed to the removal of other stems hindering their optimum development.

- This is also called Heck's free thinning and is a modification of crown thinning.
- Future trees are selected from the beginning and thinning being done only in favor of the selected trees.
- The trees other than future trees are removed or retained depending on whether they affect the growth of the future trees or not.
- It is also known as 'Elite thinning' as elite or alpha stems are selected.

Application

- It was applied in Teak plantation of Nilambur, Kerala

Advantage

- The trees which form the final crop grow free from interference and put on a very rapid increment
- The method of thinning is simple

Disadvantage

- It is not possible to select trees at an early stage
- If an elite tree is damaged, there may be no suitable substitute near it.

5. MAXIMUM THINNING

- It is developed by Gehrhardt as a modification of Heck's free thinning
- It aims to concentrate the entire growth potential of the particular area on the retained stems, from an early stage, the number of such stems being kept at a minimum so that they are able to fully utilize the available growing space.
- It is the heaviest form of free thinning as there are no trees left other than elites.
- It may result in the deterioration of site

6. ADVANCE THINNING

- It is developed by Craib and O'Connor for wattle and pine plantation in South Africa and also known as Craib's thinning.
- A thinning done in a regular crop in anticipation of suppression
- The main object is that trees should be removed before they actually adversely affect the better growing individuals.

Application

- It has been applied in Khote salla, Sal and Teak crops in India and Pinus patula in Nepal with modification

First Thinning - It is important for any forest crop. The following factors should be considered:

- It should take place before adjoining trees check one another's growth
- The first thinning should not be postponed on the ground that the poles obtained will be non-saleable or uneconomic.
- The age of first thinning should be taken on the basis of height or size attained according to the growth.
- The heavy thinnings should not be carried out on poorer sites, drier areas and steeper slopes
- The light demander species may require heavier thinnings as compared to the shade bearer species.

Thinning Cycle

- It is planned interval which elapses between successive thinnings in the same area.
- Thinning cycle should be shorter during rapid growth and longer during periods of slower growth

Thinning Intensity

- It is an indication in numerical terms the extent to which the crop is thinned.
- It is described by the terms light and heavy according to the number of trees are removed

Thinning Regime

- It is the whole set of thinnings carried out in a crop from the earliest stage to maturity

- It may have one kind of thinning or more. So, the complete set of thinnings carried out in the crop throughout its life is the thinning regime.

Thinning Practice and Control

Two control systems are widely used, one based on basal area, the other on number of trees.

A. Basal Area Control

In this system the object is to thin to a certain after-thinning basal area. This is achieved by estimating the before-thinning basal area, marking the trees to be thinned, and then estimating the after-thinning basal area.

B. Stem Number Control

This method is simpler and more common than basal area control; thinning follows prescribed stocking levels for a stand of a particular species, age, and growth rate. The number of trees to be thinned per hectare at each thinning is stipulated.

Thinning in Mixed Plantations

- It consists of species with varying rates of growth and silvicultural treatments, so thinning is difficult and priority should be fixed for various species.
- Crown thinning is the most practical way as it provides retention of the suppressed and the dominated trees.

Thinning in coppice crops

- If the object of coppice crop is fuel wood production, no thinning is done as it has no effect on total volume production.
- When the object is production of pole or small sized timber, then the number of coppice shoots is reduced to two per stool in first thinning and one in second thinning.

Thinning in Irregular crops

- It is extremely difficult to thin irregular crop due to the variations in age, size and even species.
- **Selection thinning** is largely used method. It is carried out in all canopy classes by removing the trees of following characteristics:
  - Dead, dying and diseased trees
  - Inferior trees restricting the development of their neighbours
  - Trees which are less valuable than their neighbours
  - Trees which are of no special importance with regards to a desirable crop mixture
  - Inferior trees standing over groups of well-grown advance growth which may also be thinned

Negative effects of Thinning -Thinning may also have some negative effects.

1. Increase in taper. This may reduce slightly the percentage utilization of the log.
2. Potential increase in coarseness of branches and knot size. For this reason high pruning is often done in conjunction with thinning.
3. More rapid diameter growth. This may lead to slightly less dense wood.
4. Damage to the stand and soil.

D. PRUNING

- The presence of the branches makes the wood of the stem knotty and defective, and also to some extent, decreases the height increment of the bole.
- In order to produce knot free quality timber, it is necessary that branches may be removed from the major portion of the stem.

- The operation of 'removal **of live or dead branches or multiple leaders from standing trees for the improvement of the tree or its timber'** is known as pruning.

Based on the kind of branches removed, pruning may be classified into:

- **Dry pruning** – pruning of dead branches
- **Green pruning** – pruning of living branches

According to the agency of pruning, it is classified into:

- **Natural pruning or self-pruning**– the natural death and fall of branches of standing trees from such causes as deficiency of light, decay, snow etc.
- **Artificial pruning** – done by forester without waiting for nature to do it in dense natural forest or plantations.

The following measures should be adopted during pruning:

- It should be confined to the species in which knot-free timber is an important requisite
- It should be started early in the life of the crop, so that the braches to be punned
- It should be done on the best stems which are likely to form the final crop
- The height up to which pruning is done should be as low as possible
- The branches are cut with the stem without leaving splinters of branch wood and without damaging the bark.

Bud pruning

- It is rubbing off the lateral buds to prevent the development of branches as a measure to obtain knot-free timber
- It is applied in Salix, poplar and pine species
- However, it is not been widely practiced because the branchless poles often get damaged by poles

E. Improvement Felling

- It is done to improve the condition of the forest generally degraded due to heavy felling, grazing and burning in the past
- It is the removal of less valuable trees in a crop in the interest of better growth of the more valuable individuals.
- It is applied to mixed uneven aged forests.
- Operations to be done are:
  - Felling of dead, dying and diseased trees
  - Felling of saleable unsound over mature trees which are not likely to survive up to next felling
  - Felling of unsound or badly shaped mature or immature trees provided that their removal will benefit better trees of the same or more valuable species
  - Cutting back of badly shaped and damaged saplings and advance growth expected to give better coppice shoots
  - Thinning of congested groups of poles
  - Removal of undesirable undergrowth of trees of the inferior species interfering favored species
  - Climber cutting

F. CLIMBER CONTROL

- Climbers are herbaceous or woody plants that climb up trees by twining round them or by holding on to them by tendrils, hooks or aerial roots
- Climbers are menace for the regeneration and forest crops as they adversely affect growth of young plants
- Climbers are controlled by cutting or up rooting them regularly

G. GIRDLING

- It is cutting through bark and outer living layers of wood in a continuous incision all round the bole of a tree.

- It is done to kill trees of inferior species where their removal by felling is either uneconomical or not desirable for fear damaging young regeneration or fear of increasing fire hazards
- Food is not supplied to the roots and water with dissolved nutrients are not reached to the crown
- It is usually done on trees which are more than 20 cm in diameter

H. PRESCRIBED OR CONTROLLED BURNING

- Fire, like cutting, can be used both constructively and destructively in handling the forest
- The practice of using regulated fires to reduce or eliminate the incorporated organic matter of the forest floor or low, undesirable vegetation is called prescribed or controlled burning

Effects of prescribed burning

1. Improvement in soil and undergrowth conditions for inducing natural regeneration
   - It results in increase in bacterial activity with the result that nitrate production is augmented which consumes un-decomposed litter and makes potash available
   - It reduces the density of undergrowth and makes conditions suitable for natural regeneration to come up.
   - It reduces the weed growth and provides a clean seed bed
2. Clearance of site for artificial regeneration
   - Fire is used in clearing plantation sites of weeds, grasses, shrubs and felling refuse
   - It provides clean seed bed and reduces the cost of weeding to be done later
3. Hazard reduction - It eliminates most of the readily inflammable materials and thus reduces the damage that may occur from an accidental summer fire
4. Improvement of grazing - Burning at the end of the dormant season accelerates the sprouting of green grass at the very time when the animals are most likely to be starving
5. *Recreation management* - Burning can be employed to maintain a park-like appearance in stands that would otherwise develop understory jungles
6. Control of pest - It can be used for the control of the pests

I. SALVAGE CUTTINGS

It is done for removing trees that have been or are in imminent danger of being killed or damaged by injurious agencies. It aimed at capturing the highly perishable values in trees that are seriously damaged, dying or already dead.

J. SANITATION CUTTINGS

It involves the elimination of trees that have been attacked or appear in imminent danger of attack by dangerous insects and fungi in order to prevent from spreading other trees.

UNIT V. AFFORESTATION OF VARIOUS AREAS

5.1 Afforestation of denuded hill slopes

Afforestaion in denuded hill slopes is necessary not only for productive and bioaesthetic reasons but also for conservation of soil and water

Locality factors

- Soil is poor, shallow and stony
- Excessive soil erosion has washed away the top soil
- Excessive run off results in low soil moisture content
- Grazing is very high

Soil preparation- It is done either by (a) contour trenches or (b) patches or pits

(a) Contour trenches

- It is usually made on slopes up to 20% as the operation becomes costly on steeper slopes
- They are usually made with the help of any leveling instrument like Abney's level or 'A' frame.
- The trenches may be continuous or interrupted. the interrupted trenches are considered better.

(b) Patches or pits

- It is done where the slope is rocky and contour trenches cannot be made.
- Patches or pits are made for sowing and planting respectively.

Choices of species -Different species are planted under varying conditions.
Moist sub tropical - *Pinus roxburghii*
Dry sub tropical - *Acacia catechu, Prosopis juliflora, Robinia pseudoacacia*
Temperate - *Pinus wallichiana, Cedrus deodara*

Method of raising plants

- Planting of seedlings raised in the nursery is the best method while some plants are raised successfully by sowing
- Weeding may have to be carried out once or twice depending upon the local conditions

2.0 Afforestation of abandoned cultivated lands

Locality factors

- Soil fertility is low due to raising of agricultural crops without manuaring and washing away of the top soil
- Drainage, aeration and moisture content of the soil is also poor
- As the land has been under cultivation for a long time, beneficial soil organisms associated with tree growth disappear
- Weeds may be very heavy as the area has been without cover for years after abandonment of cultivation

Soil preparation

- It should be started immediately on abandonment of cultivation
- It can be easily done by *taungya* method
- If it is not possible, soil may be dug into strips. If area is large and plain, tractor ploughing may be done
- Conditions for improved drainage should be created

Choice of species

- Due to poor soil conditions, efforts should be made to select species found in the early stages of natural succession.

- In plain areas - *Dalbergia sissoo, Eucalyptus hybrid, Terminalia tomentosa, Acacia catechu, Bombax ceiba*
- In hills - *Pinus roxburghii* and *P. wallichiana*

Method of raising plants
- Sowing and planting are both suitable
- Weeding and cleanings have to be done for several years

5.2 Afforestation of Grasslands

Locality factors
- Soil fertility is poor and biological condition is unsuitable
- Drainage, aeration and moisture content of the soil is poor
- Dense roots may be formed by some grasses like, *Imperata*
- Grasses also increase the incidence of grazing and fire

Soil preparation
- In the plains, soil preparation in strips is the only method and if possible entire area should be ploughed deep with the help of tractors and sown in strips.
- Strips should be made wide enough to prevent the grasses of interspaces overtopping them

Choice of species
- In plains- Dalbergia sissoo, Acacia catechu, Bombax ceiba, Eucalyptus hybrid
- In hills - *Populas ciliate, Grewia oppositifolia, Robinia pseudoacacia*, *Pinus roxburghii* and *P. wallichiana*

Method of raising plants
- For most of the species, sowing is the main mode of propagation
- However, *Eucalyptus* is raised by planting polythene bag plants, *Pinus roxburghii* is raised by sowing as well as by planting polythene bag plants, *Populas* is raised by cutting.

5.4 Afforestation of ravine lands

Locality factors
- Ravines continue to cut backwards and destroy even the vegetative cover on lands above them
- Soil is generally sandy to stiff clay with sufficient lime which develops into kankar pan.
- This prevents the roots of plants to reach permanent soil moisture and also prevents rain water to infiltrate to deeper layers.
- Deficiency of rainfall and excessive evaporation results in concentration of soluble salts on the surface forming infertile saline alkaline soils.

Soil preparation
- Bunds are constructed in the catchment areas for safe disposal of the excess water.
- Staggered trenches are dug at a spacing of 3.5 x 4.5 m apart on the same contour line or lines which are 4.5 m apart.
- Continuous trenches are made in the valley areas.

Choice of species
- Sandy soil- *Acacia catechu, Dalbergia sissoo, Albizzia* sps.
- Clayey soil- *Acacia Arabica, Terminalia arjuna*

Method of raising plants
- Most of the tree species are sown in one or two lines on the ridge.
- Species which are best raised by planting are raised either by entire planting or stump planting.
- Weeding and cleanings are done when necessary.

5.5 Afforestation of dry areas without irrigation

If the annual rainfall is less than 900 mm in an area, it is known as dry area.

Locality factors

- The soil varies from place to place with the underlying rock.
- Annual rainfall varies from 250 to 750 mm and it falls in a limited number of showers
- During summer, the temperature which may go as high as 50°C while during winter frosts are common
- There is a great pressure of humans and animals on the land

Soil preparation

- Soil preparation is done in such a way so as to conserve maximum moisture and also to facilitate development of deep root system. Following process is adopted
    - The soil is dug as deep as possible
    - 5.Interrupted contour trenches are made in sloping areas
    - The dug up soil is heaped to form a ridge along the portion of the trench

Choice of species

Fast growing and frost and drought resistant species are selected like *Acacia arabica, A. catechu, A. Senegal, Eucalyptus, Ziziphus jujuba, Casuarina equestifolia*.

Method of raising plants

- Most of the species can be propagated by direct sowing.
- Due to dearth of moisture, it is better if plants are raised in polythene bags are planted out.

5.6 Afforestation of dry areas with irrigation

Locality factors

- Generally the soil conditions vary from sandy to clayey with high alkanity
- A kankar pan may also occur
- Rainfall varies from place to place
- The maximum temperature reaches up to 48°C
- During the winter temperature falls considerably and severe frost are common

Soil preparation

- For effective irrigation, the area has to be thoroughly leveled
- Ploughing is done by caterpillar tractors and area is divided into large irrigation blocks
- Trenches about 30x30x30 cms are formed at a spacing of 3 meter.

Choice of species

Choice of species depends upon climatic and soil conditions. The main species planted are: *Tamarix sps, Acacia catechu, Eucalyptus, Bombax ceiba, Prosopis juliflora, Morus alba, Syzygium cumini, Populas ciliate, Dalbergia sissoo*

Method of raising plants - Trees may be raised in the following manner:

- Sowing - Direct seed sowing is done for Syzygium, acacia, Prosopis etc.
- Seedling planting - Seedlings of Eucalyptus are raised in polypots in nursery and planted during rainy season.
- Stump planting - Stumps of Dalbergia, Morus, Bombax are raised in nursery and planted during monsoon or winter rain.

5.7 Afforestation of Canal Banks

Locality factors

- The soil varies from sandy to clayey
- With the proximity of the canal, soil moisture condition is good but at places there is water-logging due to seepage

- The pressure of human and animal population is excessive as canals pass through agricultural land

Soil preparation
- It varies from site to site and state to state in India
- Hariyana technique
  - The first row is raised along the outer ridge of canal road with plants 6m apart.
  - The other rows are 3m apart with 3m spacing between plants.
- Uttar Pradesh technique
  - The strip on the left bank of the canal is planted while that on the right bank is sown
  - For planting, pits of 60cm x 60cm x 60cm are dug
  - On the outer ridge of the road plants are raised at 6m apart and subsequent rows are 3m apart

- Rajasthan technique
  - Planting is done on both sides of the canal
  - The rows are 4m apart and plants are 3m apart

Choice of species
- The choice of species depends upon the soil and climatic condition
- The main species planted are: *Dalbergia sissoo, Acacia catechu, Acacia Arabica, Eucalyptus, Populus* sps.

Method of raising plants
- Species to be planted are raised in container in the nursery
- Transplanting is done either naked root or with ball of earth or in conainers.

5.8 Afforestation of Roadside Stripes

Locality factors
- Climate conditions vary from area to area through which the road passes
- The soil varies from sandy to stiff clay
- The borrow pits upset the natural drainage and may result in conditions of water logging
- The pressure of human population is excessive

Soil preparation
- Pitting is done in winter after the winter rains when soil is easy to dug
- Pit size is usually 60 cm x 60 cm x 45cm for Mango and Shisham while 45 cm x 45 cm x 45 cm for Eucalyptus.
- Ridges or moulds are formed in water logging area
- The plants are planted in multiple rows (6-10 rows)

Choice of species
- Some suitable species are: *Azadirachta indica, Albizzia procera, Dalbergia sissoo, Eucalyptus, Ficus bengalensis, Madhuca indica, Magnifera indica, Syzyzium cumini, Terminalia arjuna*

Method of raising plants
- Nursery grown tall plants with ball of earth or raised in containers are planted
- The plants are transplanted 2-3 times in nursery to enable them to develop a bushy root system
- Pruning id done in first few years of growth

5.9 Farm Forestry

The villages situated near the forests meet their requirement of fuel from the forest, but the villages which are far from the forests, have nothing to depend upon. In the western countries, a portion of the farm is assigned to raising trees to meet the requirement of fuel and timber of the farm, in the same way as some portion of the farm is set aside for raising cash crops, vegetables etc.

Definition:
Farm Forestry is the management and use of trees on farms for commercial purposes."

Farm forestry is the practice of forestry in all its aspect on farm and village lands, generally more or less integrated with other farm operations. Thus, it is practiced in the following two categories of land:

1. Individual farmers' holding where trees can be raised on bunds, round farm house and cattle sheds.
2. Village land where groves of trees can be raised on waste land, along streams and village roads, round village schools, wells, ponds etc.

Thus, there is scope for individual enterprise for raising trees as well as collective effort for raising small forest for the village as a whole. In the first case, the ownership is that of a farmer but in the latter, the ownership is of the village community but in both cases, the villagers will be the beneficiaries.

Farm forestry incorporates commercial tree growing into farming systems. It takes many forms, including timber belts, plantations, woodlots, wide-spaced tree plantings and the sustainable management of existing stands of native vegetation.

5.9.1 Objective of farm forestry

1. To supplement production of leaf fodder, fuel wood and small timber to meet the increasing requirements of the villages
2. To release cow dung for use as manure
3. To create diverse eco-system by having trees interspersed with agriculture
4. To help the development of cottage industries and add to the income of the farmer from the sale of excess timber
5. To beautify the villages and countryside.
6. Carbon sequestration -Trees on farm land provide what is known as a 'carbon sink'.

5.10 Urban Forestry

Urban forestry is the management of trees in the urban areas. It is generally defined as the art, science and technology of managing trees and forest resources in and around urban community ecosystems for the psychological, sociological, economical and aesthetic benefits trees provide. Urban forestry embraces a multi-managerial system that includes municipal watershed, wildlife habitats and outdoor recreation opportunity, landscape design. The role of the urban forest in the temperature extremes is mentioned by various researchers.

5.10.1 What is an Urban Forest?

The urban forest exists within many scales, locations, and owners. Specifically, it can be defined as, "…the sum of all woody and associated vegetation in and around dense human settlements…" (Miller, 1997). It is the sum of park trees, street trees, residential trees, as well as riparian vegetation. It includes trees on unused property, trees in utility rights-of-way and transportation corridors. Trees within an urban forest contain a complex array of public, private, and quasi-public owners: local government agencies, private landowners, public institutions, etc.

According to Miller (1997), three things dictate the configuration of the urban forest: urban morphology, natural factors, and management. Urban morphology is the structure of the city as dictated by land use, and outlines the areas where trees can grow. Natural factors, such as soil, water, and sunlight dictate the types of vegetation that will grow, as well as the location. Management influences the urban forests by dictating the "species and ecosystems" (Miller, 1997) that people decide to incorporate in the surrounding landscape.

5.10.2 What Benefits Does an Urban Forest Offer?

There are many reasons why an urban forest is important to a community. It provides many economic, aesthetic, environmental, community, and health benefits.

- **Increased Property Values**

Property values are increased by 15-20% when homes are surrounded by large trees or are located on well-shaded streets. Furthermore, the value of trees and the urban forest appreciates over time, which provides an important economic asset to a municipality.

- **Decreased Energy Use**

A mature tree transpires up to 100 gallons of water a day, which is equivalent to five large air conditioners operating 20 hours a day, resulting in temperature decreases of 5-12 degrees. Shade trees can also reduce temperature on building surfaces by 16 degrees, which cuts air conditioner costs. Both of these factors are useful in mitigating the heat island effect that afflicts urban areas. Furthermore, windbreaks formed by trees can reduce heating costs in winter by 20%-30% (UCCEF, 2001).

- **Improvement in Air Quality**

An urban forest is very effective at improving air quality. Consider following statistics (UCCEF, 2001):

  - Dust counts can be decreased by 75% downwind of urban plantings
  - An 80-foot beech tree daily removes the amount of carbon dioxide produced by two single-family dwellings
  - Fumes and bad odors can be intercepted by trees or masked by their more pleasing odors
  - Over a 50-year lifetime, a tree produces oxygen worth $31,250

- **Reduction in Storm water Runoff**

An urban forest reduces runoff by slowing storm water down so it can infiltrate into the soil and also by keeping the soil aerated to allow greater percolation of water. A reduction in runoff can be especially important in an urban area that has a large amount of impervious space.

- **Decrease in Soil Erosion**

Trees decrease soil erosion in a couple of ways. First, their roots serve to anchor the soil, which helps to mitigate the erosive effects of wind and water. The tree canopy also serves to intercept water during storms, so less water is hitting the ground's surface and with less force. It has been estimated that over a 50-year lifetime, one tree controls $31,250 worth of soil erosion (UCCEF, 2001).

- **Improvement in Water Quality**

An urban forest improves water quality in a variety of ways. First, it reduces storm water runoff that can carry numerous pollutants as well as large amounts of sediment to water bodies. It also reduces the amount of soil erosion and sedimentation that will be carried in runoff. It is estimated that over a 50-year lifetime, a tree recycles $37,500 worth of water (UCCEF, 2001).

- **Creation of Wildlife Habitat**

Urban areas usually do not contain large areas suitable for natural habitats and furthermore, development creates habitat fragmentation. However, an urban forest can house many creatures such as birds and squirrels that do not need large areas to survive.

- **Increase in Community Pride**

Trees add beauty to urban areas. Community residents take pride in the fact that their city is an attractive place to live as well as to visit.

- **Increase in Recreational Opportunities**

Large tracts of urban forest such as parks can create ideal places for residents and visitors to relax and spend some time outside. The urban forest presents a myriad of recreational activities such as bird watching, sports, and hiking.

- **Improvement in Health and Well-being**

Urban forests can directly and indirectly improve the health and well-being of the community's residents. This occurs indirectly through the improvement of air and water quality. Furthermore, studies have shown that hospital patients recuperate better if they can see trees from their recovery room windows (UCCEF, 2001). Overall, the presence of trees can improve the quality of life for city residents.

- **Reduction of noise levels**

According to some studies, tree buffers can reduce unwanted noise by up to 50% (UCCEF, 2001). Due to the increased density and mix of uses in a city, this can be very important to improving the quality of life for residents.

- **Carbon sink and carbon credit**

Trees in urban areas will contribute to remove CO2 from the atmosphere by sequestering or locking up carbon in their plant tissues and releasing oxygen (O2) into the atmosphere. They therefore provide what is known as a 'carbon sink'. Carbon credits may be generated which may be sold to other emitting industries.