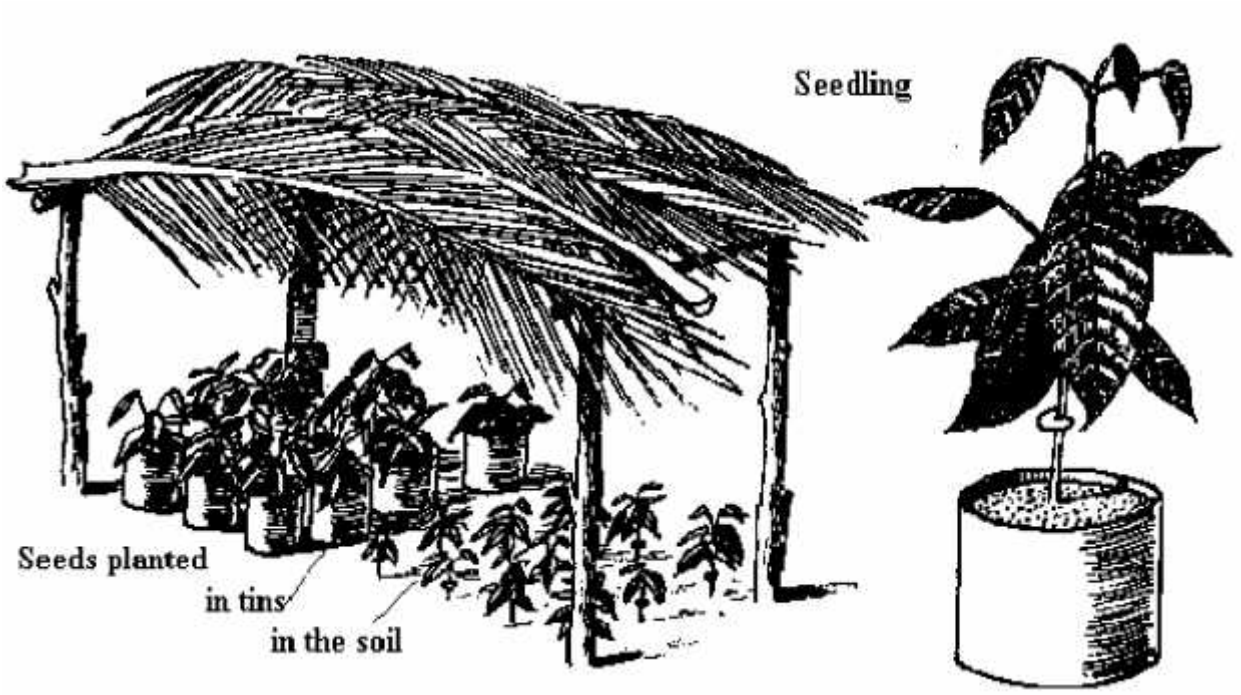
CLASS NOTE ON

# Plantation Silviculture




## Reading Material for B.Sc. 2nd year 1st Semester

## IOF Hetauda

*Written By*
*Professor J.N. Yadav*
*IOF Hetauda*

*Compiled By*
*Bishowraj Pandit*
*DoF, Nepal*

# UNIT 1 INTRODUCTION

## 1.1 Plantation Forests:

A plantation is defined as "a forest crop or stand raised artificially, either by sowing or planting." This may seem simple but the words 'artificial' or 'manmade' need further definition, for example; when a new forest is established on grass land, such afforestation is clearly artificial and can be termed a plantation. But where an existing forest is regenerated by enrichment through tree seedlings are planted, the general appearance is usually not very like a plantation, at least often not for many years.

The first consideration is one of origin. Between the extremes of afforestation and unaided natural regeneration of indigenous forest, there is a range of forest conditions where intervention occurs to a greater or lesser extent in regeneration. Five forest types can be identified according to their origin.

1. Afforestation of bare land where there has been no forest for at least 50 years. All afforestation of grassland falls into the categories and planting to stabilize sand-dunes etc.

2. Reforestation of land which has carried forest within the last 50 years but where the previous crop is replaced by an essentially different one. An example, where forest is logged, cleared and then part replanted with a single tree species (As Sagarnath, Ratuwamai plantation) and part left to natural regeneration as is being carried out in south west Malaysia.

3. Reforestation of land which has carried forest within the last 50 years by renewal of essentially the same crop as before. This is much less common since one of the advantages of planting trees is the opportunity to introduce a new and more productive one, e.g. *Araucaria* plantation in Papua New Guinea, *Triplochiton* plantation in west Africa are examples of this forest type since the previous forest was often dominated by the same species as used in the plantation.

4. Forest established by natural regeneration with deliberate silvicultural intervention and manipulation.

5. Forest which have regenerated naturally without human assistance, e.g. most natural forests in the tropics.

Plantations are the forest types in class 1-3 above, that is, artificial regeneration is the basic criterion.

In addition to their origin several other characteristics tend to be associated with manmade forest or plantation.

**Why plantation?**

The main causes of forest destruction are well known and many accounts have appeared of which are particularly useful, while Palo's (1987) analysis indicates the complexity and interactions.

1. Clearance for agriculture: between 1900-1965 about half of the forest in developing countries was cleared for agriculture. World Bank (1978)

2. Intensive logging for veneer saw timber etc.

3. Exploitation for charcoal, fire wood, poles and other domestic uses.

4. Shifting cultivation on too short a cycle especially at the forest fringe; 250 million ha. Of tropical forest are presently affected by shifting agriculture.

5. Urban and industrial expansion including mining and hydroelectric scheme over the whole world; this takes up 12 million ha of land each year.

6. Especially in arid areas, over grazing and gathering fodder for livestock, though this should not be overstressed.

7. Accidental or deliberate burning of forest; in 1982 fire burnt 3 million ha. of low land rain forest in Kalimantan and large areas more destroyed in Australia, America, Brazil etc.

8. Revenges of war: national and international war destroyed many forest.

**Objectives of plantation:**

1. To supplement natural regeneration.
2. Artificial plantation to replace natural regeneration.
3. Restocking of degraded forest.
4. Change in crop composition.
5. Introduction of exotics.
6. To increase the yield from the plantation forest.
7. To shorten the rotation.
8. To locate the forest with relation to the location of the industry.
9. To improve the agro-ecosystem, control the erosion.
10. To increase the employment opportunity/potential.
11. To raise the windbreak and shelterbelt.
12. To increase the aesthetic value.
13. To ameliorate the overall environment.
14. To increase the biodiversity.
15. To balance the ecosystem etc.

METHODAS OF REGENERATION

I. Natural regeneration
II. Artificial Regeneration
III. Natural regeneration supplemented by artificial regeneration

**I. Natural Regeneration:**

Natural regeneration is defined as "The renewal of a forest crop by self-sown seed or by coppice or root suckers." It also refers to the crop so obtained. Thus the natural regeneration may be obtained from the following two main sources.

A) From seed and

B) From vegetative parts

A) Natural regeneration from seed: Natural regeneration from seed depends upon;

1. Seed production
2. Seed dispersal
3. Seed germination
4. Establishment

**1. Seed production**: depends upon;

- Species
- Age of tree
- Size of crown
- Climate and other external factors

**2. Seed dispersal**: seed dispersal by

- By wind: - light and winged seeds.
- By water: - near riverbank plants which can be floated.
- By gravity: - in slopy area large, heavy seeds.
- By animals: - by birds, by human beings- edible fruit seeds.

**3. See germination**: Germination of seed depends upon

a) Internal factors b) External factors

a) Internal factors: are

- Permeability of water
- Permeability of oxygen
- Development of embryo
- After ripening
- Viability
- Size of seed
- Germination capacity and germinative energy

Germination capacity is defined as "The percentage by number of seeds in a given sample that actually germinate, irrespective of time."

Germinative energy is defined as "The percentage by number, of seeds in a given sample that have germinated upto the time when the rate of germination (number of seeds germinating per day) reaches its pick."

Plant percent is defined as percentage of the number of the seeds in a sample that develop into seedlings at the end of the first growing season.

b) External factors: External factors are the factors of environment which affect germination. They are;

- Moisture
- Air
- Temperature
- Light
- Seed bed

**4. Seedling establishment**: Seedling establishment is defined as "The development of a new crop, naturally or assisted, to a stage when the young regeneration, natural or artificial, is considered safe from normal adverse influences such as frost, drought or weeds and no longer needs special protection or tending operations other than cleaning, thinning and pruning." The following factors affect establishment of seedlings;

i. Development of roots
ii. Soil condition
iii. Light
iv. Other climatic factors - extremely high or low temperature
v. Condition of grass and other competing weed growth
vi. Grazing and browsing
vii. Drip
viii. Composition of the crop - A mixed crop is believed to create more favorable condition for seedling establishment than pure crops.

**II. Artificial Regeneration:**

Artificial regeneration is defined as 'The renewal of a forest crop by sowing, planting or other artificial methods." It also refers to the crop so obtained'. Normally such a crop is called plantation, which is defined as a forest crop raised artificially, either by sowing or planting nursery grown seedlings or seedlings collected from forest.'

**Objectives of artificial Regeneration:**

A) Reforestation, and
B) Afforestation

**Objectives of reforestation:**

1. To supplement natural regeneration
2. To give up natural regeneration in favor of artificial regeneration
3. To restock forests destroyed by fire and other biotic factors

4. To change the crop composition
5. To introduce exotic.

**Objectives of manmade/plantation forest:**

1. Increase the yield from forest to meet the fast increasing demand of timber for building construction, industries, defense and communications.
2. Shorten the rotation by raising fast growing species.
3. Locating forests with relation to the location of industries.
4. Meeting the demand of agricultural implements, hosing, fodder and firewood of the rural population.
5. Improvement of agro-ecosystem, control of erosion and beautification of countryside.
6. Concentration of work resulting in easier supervision, easier mechanization of operation, cheaper logging and extraction, and
7. Increasing employment potential.

**Factors affecting the choice between Artificial and Natural regeneration;**

- Risk of loss and deterioration of soil
- Crop composition
- Genetic consideration
- Risk of damage by pest
- Flexibility of operation
- Density of stocking
- Yield
- Time factor

**Essential preliminary consideration:**

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

**I. Choice of species: -** depends on the following factors.

a) Climate and micro-climate
b) Soil condition
   - Lime rich soil
   - Stiff kankar clay
   - Clayey soil
   - Soils with soluble salt
c) Stage of succession
d) Objective of management
e) Consumer's requirement
f) Growth rate
g) Availability of suitable exotic
h) Ease of establishment
i) Cost
j) Effect on site

**Mixture in plantation:** In order to decide (pure or mixed), merits and demerits of pure and mixed crops may be assessed from the point of view of following considerations:-

1. Soil deterioration
2. Resistance to diseases
3. Damaged by wild animals
4. Increment of total yield
5. Difficulty in execution of silvicultural operations as well as management.

**Kinds of Mixture:**

**A) Temporary mixture:** For following objectives

Objectives of temporary mixture;

a) Providing protection against adverse factors.
b) Providing competition in the early stage to obtain better bole form.
c) Providing additional revenue.
d) Providing covers to the ground and suppression of weeds.

**B) Permanent mixture:** In which the mixed species remains with main species throughout the rotation of the crop.

Objective: - to avoid risk to which pure crops are exposed.

Kinds of Permanent mixture:

a) Horizontal or even aged mixture
b) Vertical or uneven aged mixture or storeyed mixture.

Pattern of mixture:

a) Intimate mixture
b) Line mixture
c) Strip mixture
d) Block mixture

**II. Selection of site**

**III. Choice of methods of artificial regeneration**

a) Direct seed sowing or
b) Seedling planting

Advantages of sowing
Disadvantages of sowing

Advantages of planting
Disadvantages of planting

The choice between the two methods (sowing or planting) of artificial regeneration depends upon;

- The species to be raised
- Condition of site
- Availability of seed
- Cost

***Spacing:*** - Spacing varies with species and the local conditions. The following factors govern the spacing;

a) Rate of growth of species: - Fast growing species have wider spacing and slow growing species have closer spacing.
b) Habit of branching: - large number of branches reduce the volume and value of timbers so, plant in close spacing.
c) Number of annual rings per centimeter: - this type of denser wood species wider spacing.
d) Height of planting material: - If tall plants are to be used for planting, the spacing should be wider, if small planting stock is to be planted spacing should be closer.
e) Site factor: - In dry area, spacing should be closer.

f) Inter cultivation: - wider spacing for tractor ploughing and cultivation of agricultural crops, as a intercropping tree with agro-forestry crops.
g) Market for small sized timber: - The crop raised in closer spacing.
h) Fruit production as objective: - Spacing should be wider depends on fruit bearing species.
i) Cost: - Close spacing requires much cost than wider spacing. Therefore availability of funds has a great influence on the spacing to be adopted.

## 1.2 Methods of Artificial Regeneration:

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

### 1.2.2 Regeneration from seed

**Kinds of Sowing:** sowing may be done in any of the following ways:

**a) Broad-cast Sowing**: It is the process of scattering of seed over the whole area, either that on which the crop is to be raised directly or a nursery bed. It is generally recommended for stocking burnt areas, abandoned cultivation, landslides and grassy blanks.

**b) Line Sowing**: In this method, sowing of seed is done in drills or single lines. Drills or lines are made at pre-determined intervals after digging soil in those places. It may be continuous line sowing when drill is made from one end of plantation to other end while it may also be uninterrupted line sowing in which the area consists of dug up and sown portion alternating with undug and unsown portion. If the sown portion of line is opposite to unsown portion of adjacent lines it is called interrupted and staggered line sowing.

**c) Strip Sowing**: In this method, seed is sown in narrow strip prepared usually at definite intervals from one another and are generally 45cm to 90cm or even 120cm wide. Like line sowing strip sowing may be continuous, interrupted and staggered.

Line and Strip sowing are done either on ridges or in trenches, depending on rainfall. In high rainfall, moist and areas liable to water logging sowing is done on ridges (10 to 20cm higher than ground level) and such sowing is called ridge sowing where as in dry and low rainfall areas, the seed is sown in trench and called trench sowing.

In areas with uncertain rainfall ridge ditch sowing is done in which earth is filled back in trench in sloping manner leaving part of trench unfilled. In case of poor rainfall, lowest row sowing will be successful, in case of moderate rainfall; the middle row will be successful while in heavy rainfall ridge sowing will be successful.

**d) Patch Sowing**: It is the sowing of seed in specially prepared patches i.e. circular or rectangular made at regular intervals. It's important merit is that the patch may serve as small nurseries inside the plantation.

In high rainfall areas or areas liable to water logging patch sowing is done on mound called mound sowing. Mounds are usually 1.2m × 1.2m at base and 60cm × 60cm at top while in dry areas, sowing is done in pits called pit sowing and are usually 1.5m long, 1.5m wide & 30cm deep.

**e) Dibbling**: In this method, sowing is done in shallow holes made with suitable instruments at definite intervals and is used for such species as *Juglans,* etc which produce large seeds.

### 1.2.2 Regeneration from vegetative parts (sprouting, root suckers, and coppice etc.)

Regeneration from vegetative parts can be obtained by any of the following methods:

- Coppice
- Root sucker
- Cutting
- Layering
- Grafting
- Budding
- Sprouting

REGENERATION FROM SPROUTING: Please consult books and internet.

REGENERATION FROM ROOT SUCKERS

Root sucker is a shoot rising from the root of a woody plant. It is that method of vegetative reproduction in which a root of a plant is partially or wholly cut to produce a shoot called root sucker.

Natural regeneration by root suckers is not being attempted on any large scale anywhere in this country. This method used to be followed, sometimes, on the canal bank plantations in India and the chief species in which this was affected was sissoo. Where this method was followed, it was usual to dig continuous or discontinuous circular trenches with diameter of about 6 m round the isolated trees so that their roots may be severed and root suckers produced, which, with tending, could be developed into trees.

The trees produced in this way are liable to wind-throw and poor in growth and therefore this method is not being favoured now. *Diospyros* root suckers are sometimes encouraged because the root suckers produce best *biri* leaves.

REGENERATION FROM COPPICE

Coppice is that method of reproduction in which the tree, plants or, the seedlings of a species when cut from near the ground level, produce coppice shoots. Coppice shoot is defined as 'a shoot arising from an adventitious bud at the base of a woody plant that has been cut near the ground or brut back'.

Natural regeneration by coppice can be obtained either by:

(1) Seedling coppice; or (2) Stool coppice

**(1) Seedling coppice** is defined as the 'coppice shoots arising from the base of seedling that have been cut or burnt back'. This method of obtaining natural regeneration is used for cutting back woody shoots and established reproduction which is not making any progress so that they may produce vigorous shoots and soon develop into saplings and later into poles. It is generally used in case of Sal and Teak.

**(2) Stool coppice** is the coppice arising from the stool or a living stump. In this method, regeneration is obtained from the shoots arising from the adventitious buds of the stump of felled tree. The coppic shoots generally arise either from near the base of the stump or from its top. Of the two, those arising from near the base are better because they get established easily. The shoots arising from near the top of the stump are liable to be damaged by the rotting of the upper portion of the stump as well as by wind, etc.

**UNIT 2 NURSERY OPERATIONS**

**Nursery:**

A Nursery is an area where plants are raised for subsequent planting out in the field. For all plantation works involving the use of seedlings, root shoot cuttings, transplants etc. these stocks have got in the nursery.

In artificial regeneration, plants have first to be raised under controlled conditions, where they are able to survive through the critical stages in the first few months or years of their lives. Thereafter, they are planted out in the field to eventually grow into a full-fledged forest.

## 2.1 Objectives and Importance of nursery:

**Importance of forest nursery:**

The forest nursery from a very important part of artificial regeneration operations- for it supplies the basic input - the nursery stock or planting stocks. In the recent past, there has been a support of plantation activities in a big way in the forestry sector, largely brought about by large-scale afforestation operation efforts to raise short rotation, fast growing species and by the introduction of exotic species such as *Eucalypyus spp., leucaena spp., Tropical pines, Tectona grandis, Acassia spp. etc.* These have been brought from the nursery.

**Objectives of Forest Nursery:**

A forest nursery may be established and maintained for the following objectives.

- To provide seedlings every year, even in case of species which do not seed every year. Seed collected during moderate to good seed years can be kept stored properly sown every year (depending on its viability) in a nursery to ensure a regular supply.

- To provide hardened plants for specific sites such as dryer to barren areas, roadsides etc. where only very healthy plants would give uniform success. These can be raised only in the Nursery.

- To raise tall and healthy plants for successful road, cannel and avenue plantation.

- To grow an adequate stock of slow growing species. A number of forest species are rather slow growing, due to which, if their seeds are sown directly in the field, the seedlings are likely to fail largely because of intense competition. However, in the nursery, proper conditions for their growth can be maintained, and when they have passed the critical stage of their growth, they can confidently be planted-out in the field.

- To try and grow exotic species such as *Eucalyptus, Teak, Tropical pines, Acassias, Cassias, Ceiba pentendra* etc. These can best be introduced by nursery raised seedlings.

- To provide stock for replacement of casualty or beating up of failures, it is best done by nursery-raised seedlings.

## 2.2 Types of nursery:

Nurseries are classified either on the basis of irrigation facility or duration of their use and on the basis of production practices.

***On the basis of duration and their use nurseries are classified into:***

**(a) Temporary nursery:**

It is a nursery that is maintained for supplying nursery stocks for a short period after which it is abandoned. Normally it is made in the plantation area or in previous year's plantation if it is closed by. It is also referred to as field nursery formed in or adjoining the plantation area. As it is also intended to meet the requirements of the limited area, it is usually small in size which may be increased or decreased with the demand for planting materials.

The main features of temporary nurseries are:-

(i) It is usually established for a short period of time, comparatively smaller in size, but it may be increased or decreased with the demand for planting stocks.
(ii) It is located near planting or inside the planting area and is used for supplementing the natural regeneration or for casualty replacement.
(iii) It is abandoned after a couple of years when soil productivity falls down and/or planting area becomes distant.
(iv) Manuring is not necessary because of freshly felled forest area contains rich organic matter in soils good enough for a short period of time.
(v) There is an opportunity to raise the nursery stock in the same vegetational zone as the plantation area. This is particularly true for the hilly regions.
(vi) Elaborate soil preparation is not necessary.
(vii) The cost of transportation to the planting sites is low on account of nearness. This is an important factor when the nursery stock is of larger size or has to be transported in containers as in the case of *Chirpine.*
(viii) Where mixed crops with different soils requirement is to be raised, temporary nurseries are better than permanent ones.
(ix) The gap between lifting the stock from the nursery and actual planting in the field is substantially reduced.
(x) Intensive supervision is difficult an account of their scattered nature of location.

**Advantages:**

(i) It is usually made in newly cleared sites fairly rich in humus; and therefore does not require any manuring. *Eucalyptus* nurseries are an exception to the general rules.
(ii) There is minimum trouble with the weeds, destructive insects and diseases.
(iii) It enables raising of species in their optimum altitudinal zone in hills.
(iv) It also enables easy, quick and cheap transport of planting stock without any serious damage or shock.
(v) Advantageous under condition where the requirement of plants varies from year to year, and where planting is largely.

**Disadvantages:**

(i) Several temporary nurseries would be costly.

(ii) Several temporary nurseries are difficult to supervise.
(iii) Proper supervision is not possible as it is made in out of way places.
(iv) In the absence of irrigation facility, the growth of seedlings is, usually slow and there is usually heavy mortality in them.
(v) It is relatively costlier to maintain as compare to a permanent nursery.

**(b) Permanent nursery:**

It is a nursery established permanently for the continuously production of planting stocks for a long time on a permanent basis. The duration of service life of a permanent nursery is long and it is maintained till seedlings can be raised in it at reasonable cost. It is intended to meet the requirements of one or more ranges and it is relatively larger in extent.

The main features of permanent nurseries are:-

(i) Feet for large and intensive work, where seedlings or transplants are grown year after year on the same site. It may continue for 50 or more years.
(ii) They should be situated at a place where supervision is easy, communication facilities are available, and easily labour should be available throughout the year.
(iii) They are of centrally situated, so as to serve as large an area as possible.
(iv) The more capital outlay can be invested as it can be spread over a long period of time.
(v) Intensive manuring and soil working can be done so that vigorous stocks are raised year after year on the same site.
(vi) Centrally located with respect to planting area, so as to reduce transporting cost.
(vii) It is usually made in a control place in the range near the quarter of some subordinate for proper supervision.
(viii) Used for large scale afforestation works, or distribution to the villagers under community and private forestry programme.
(ix) In hills, they are located at the lowest altitude in a way the sites are easily accessible and seedlings are grown without much difficulties in a shorter time.
(x) The works of nurseries could be started earlier and there would be less injury by frost.
(xi) They require a large labour force; original cost of formation is high but is cheaper in the long run than several temporary nurseries.
(xii) They are large in extent and intensively managed. A high level of both materials and human input is required.
(xiii) There is greater economy in nursery operation and supervision.

**Advantages:**

(i) Permanent nursery can supply different types of adequate planting stocks, such as root shoot cuttings, grafted plants, plants from enriched, layering, budding, seedlings from seeds, polypot seedlings, bare root seedlings with bole of earth etc. for long time.
(ii) Duration of service life is long and production cost is reasonable.
(iii) It can meet the requirement of more ranges.
(iv) Supervision cost is low and can be easily supervised.
(v) Easy transport of nursery stocks due to nearness of roads.
(vi) Plants are raised year after year for a long time on same site.

**Disadvantages:**

(i) Transportation of seedlings is difficult and costly.
(ii) Establishment cost is high.
(iii) Manuring of beds every year and intensive soil working is essential.
(iv) Requires large labour force throughout the year which is difficult to available in agricultural seasons.

**(c) Extension nursery:**

***On the basis of irrigation facility nurseries are classified into:-***

**(a) Dry nursery:**

It is a nursery that is maintained without any irrigation or other artificial watering. This type of nursery is usually unirrigated or ones not having a permanent source of water. Not very successful and used only for species which do not need a large quantity of water. e.g. *Acassia's* & *Cassia's* varieties. Mostly this type of nursery is established in dry, arid and in semi arid area.

**(b) Wet nursery:**

It is a nursery that is maintained by irrigation or other artificial watering during the dry periods. Actually this is irrigated nursery having a perennial source of water. It is possible to raise large planting stocks in such nursery. It may be temporary or permanent. Mostly the species which requires much water are raised in this type of nursery.

***Classification of nursery on the basis of production practices:-***

Besides, government nurseries, seedlings are being raised in non-government forest nurseries. These nurseries are called farmer's nurseries. They came into existence under social, private, school, women and village development nurseries etc.

**(a) Social/Community nursery:**

Raising of seedlings in nurseries by the society for the plantation of community owned areas. It is also called the community nursery. The land under society is planted using social nurseries raised seedlings. All the inputs and outputs invested and incomes shared by the society

**(b) Private nursery:**

Raising the seedlings or establishment of nursery in private land by individual farmer. In this case only one family is involved. In this type nursery seedlings are first used for planting in personal owned lands and the extra seedlings can be sold to other. All the responsibility is to be a particular owner.

**(c) School nursery:**

It is established in school compound involving the students for practice and demonstration of student, planting in school lands (inside and outside the school's lands) sometimes seedlings are sold to others and output is kept in school fund.

**(d) Women nurseries:**

In some village there are women's organizations say Mahila mandal or Aama Samuha establishes nursery to grow different types and species of seedlings for seeding through the involvement of the women members for extension and strengthening the women's organization fund and are used for the development of women.

**(e) Village nurseries:**

Village nurseries are established by the contribution of village development committee (VDC) for the planting of village/VDC owned lands, road sides in VDC and for the distribution of seedlings to the farmers on nominal cost.

**(f) Commercial nurseries:**

The nurseries which are established for commercial purpose in which all types of different species, {(forestry- fuel, fodder, timber), fruits, flowers, ornamental etc} are raised for sale. They may be temporary or permanent in nature.

**(g) Farmers nurseries:**

The nurseries which are established by the group of farmers to raise forest and ornamental species for planting in their own lands for fuelwood, fodder and timber purposes, generally for their personal or save the sold money. But in our country, farmers' nurseries are established by the help of community forestry and other projects. In such types of nurseries, seeds and other technical helps are provided by the projects authorities and/or the department of forest even they assure to purchase the seedlings from them.

## 2.3 Site Selection for Nursery:

This is a very vital issue and is one of the most difficult task in nursery management. Site for nursery should be chosen with utmost care and caution. It needs careful evaluation of various factors, particularly mountains areas where it is difficult to get favorable conditions which should be borne in mind are location, terrain, aspect, soil conditions, availability of water, distance from road, distance from plantation sites, distance from market, wind, frost, hail, damage from wildlife, fire and flood etc.

**1. Area:**

The first requirement of the forest nursery planning is the area where it should be constructed. Area should be sufficient for meeting the requirement of proposed plantations, villagers, educational institution, and other needy organizations. The demand for seedlings should be assessed in advance. The area of a nursery depends upon the following.

i. Number of species and number of plants to be raised.
ii. The age of the seedlings or transplants required.
iii. Number of pricking out to be done.
iv. Number of seedlings and types of seedlings or transplants required, depending on the spacement to be adoptedin the plantation.
v. Nature of nursery whether temporary or permanent.

vi. Allowance for crop rotation or green manuring of any size of the nursery should be determined by thumb rule. One hundred thousand (one lakh) seedling can be raised in an area of 0.4 ha (1 acre). The area of nursery also depends on the total number of plants required and the spacing in the nursery beds and the width of polythene bags in case of polythene bag raised seedlings. The area can be calculated as under.

A =N/n+c

Where, A stands for area in sqm.
N for total number of plantable seedlings.
n for number of plants per sqm in the bed and
c for 25 to 30% additional area required for paths, drains, sheds, manure, seed pre-treatment, water tank, materials and store.

In case of polythene bag seedlings the area can be determined as under;

A =( N / no. of polybags per sq. metre ) + C

Where A, N and C stand for same. Normally the diameter of filled polybags varies from 5.5 cm, 7.5 cm. should be 100 (10x10).

In practice there is 1 to 2 ha. of nursery area is sufficient for 100 ha. of planting area in our country. A guide line one may note that in India (Mumbery and Chenie) a nursery of (15x1 M) size bed sown with 10 to 15 kg of Teak seeds are sufficient for planting half a hectare at a spacement of 2m x 2m. In case of Deodar, 0.5 ha. of nursery is required for planting 12 ha. making use of 1.5year old transplants. In Bengal 0.5 ha. of nursery serves for 100 ha. of planting using one year old seedlings.

**2. <u>Location</u>:** The nursery should be situated near road, rail and should be within the radius of 5 km. from proposed plantations and villages. This may depends more on the availability of land as well. But before finally selecting the area, detailed field survey should be conducted for the identification of the area. In case forest land is not available within permissible distance and nearness to the road net work, private land can be acquired through proper procedure. Alternately, the private land may be taken on approved land rent basis. Centrally located nursery has many advantages. It is economical from transportation point of view. The more important advantage is that it takes less time for transportation of seedlings from the nursery to the planting sites. Therefore, transportation shock to plants is lesser the moisture loss of plants while in transit is less. Hence there can be better chance of survival percentage and success of plantation.

If suitable location is difficult to find as one plot, in that case the nursery can be made in tow, or three suitable plots in the same locality. This holds good if the nursery is temporary and there is provision of engaging a part time *Mali* for every twenty thousand of plants. However, in hill it may be allowable to engage a part time *Mali* for every ten thousand of nursery plants.

**3. Soil:**

Soil is the most significant factor for the success of forest nursery. The ideal soil for nursery should be sandy loam to loam in texture; it should be well drained and should be fertile. It should have good tilt and medium to small blocky structure ph value of the soil should be between the ranges of 5.5 to 7.5 and should contain organic matter not less than 2.5%. It should be free from big boulders and gravels sandy infertile soil is not suitable for nursery.

It should have good capacity of water retention. This capacity can be improved by adding compost manure (one part of manure to 4 part soil). Mature soil or established soil contains three distinct layers scientifically known as horizons. Starting at the surface are top soil, sub- soil and loose parent rock. These horizons are categorized as A- horizon, B- horizon and C-horizon respectively.

A-horizon is the mixture of completely decomposed dark coloured humus and fine soil particles containing plant nutrients. Through this horizon is thin in depth but in the basis of soil fertility. Beneath this is the sub-soil or B-horizon which contains leaching material from top soil due to rains and is rich in which at places hard pan is found formed due to washed down clay particles that has accumulated at the surface and gets compacted into a soil impenetrable hard mass which is very harmful for tree growth. Below sub-soil is the loose parent rock or C-horizon. Here in this zone the soil is in the making and under laid by bedrock.

Soil is graded according to the presence of particles in size from sand to fine silt to clay .Clay is powdery when dry. The different kind of particles in different proportions joined together is the soil texture. It is this texture of soil, which determines the ease with which root, air and water move through the soil. Loam includes all three kinds of particles viz; sand, silt and clay in varying proportions. Soil through non-living, but holds for tremendous amount of living plant material in the form of roots and other living organisms. Deeper the topsoil the more fertile, it is soil without A- horizon is infertile, before establishing a forest nursery it is necessary to study the soil profile and soil characteristics. Dragging can do this soil pit.

**4. Water supply:**

A reliable and adequate source of water supply is essential for all forest nurseries. The ideal situation is where there is a perennial stream at a higher level than the nursery level. Therefore; the nursery site should be situated near the adequate source of water (for irrigation). If irrigation is to be done by flooding or percolation the nursery should below the level of water supply.

But if there is any doubt about the flow of the stream throughout the year. The water flow should be carefully checked at the lowest period, and enquires made of local people as to whether the stream is likely to dry up or is reduced to strickle in unusually dry years. Enquiries should also be made about whether local farmers are weekly to divert the stream to irrigate their crops, when water is also needed in the nursery.

It is sometimes necessary to depend on an existing irrigation channel for water supply, but this can be risky, as framers may divert the water for their own use during critical periods. In such cases, a clear understanding on water use should be reached with the local villagers before the nursery is established. The constructions of water storage tank in the nursery, which can be filled up overnight, with mitigate these problems to some extent.

In the plains, water may have to be obtained from wells. In this case installation of a pump will be needed. One man hand operated rotary pump can supply enough water for about 30,000 plants and a two-man pump enough for 50,000 plants (Laurie1994). For large nurseries, mechanical pump or overhead tank is needed. In hills ½" pipe line continuous water supply in working hours is enough for about 1 lakh plants but in Mahabharat and in Dun (valley) where soil is well drained, two ½" or one inch pipe lines with 6 hours continuous water supply are needed.

Water requirement will vary with the climate and the species to be grown. In Zambia it is estimated that more than 30 liters per day needed per 1000 *Eucalyptus* plants in polypots. Using this figure as guide a small communial forest nursery, raising 20,000 plants in a year, well need upto 600 liters of water a day one cubic meter allowing a margin for safety. The requirement of water in lower hills and semi-aried areas minimum 2oo ml. Per plant in peak summer season (C.D. katoch1992).

**5. Availability of suitable soil:**

In nurseries where the plants are to be raised in containers, the soil of the actual nursery itself is not important, but there must be a suitable source of soil, preferably old natural forest top soil, and sand if this is needed, within easy reach of the nursery. To fill ten thousand 3" x 7" lay-flat containers, about 3M3 of soil or 2M3 of good soil plus 1M3 of sand are needed but it should be coarse sand. To fill the large containers of size 4" x 7" it will need about 5.5 M3 soil for 10,000 pots. The weight of one pot is about 300 gm. so, a nursery raising 20,000 plants each year will need about four tons of top soil plus two tons of sand or six tons together equivalent to 240-250 doko loads. Top soil of sal forest is the best if available. Seed beds and seed trays need additional qualities of soil, pines are to be raised a source of mycorrhizal soil will also be needed.

**6. Natural zonation:** As for as possible, the nursery should be located in the natural, physiographical and altitudinal zone of the species which are to be raised in it.

**7. Topography:**

For heavier soils, a gentle slope is essential but for light soils, leveled site should be selected. On average sites, a gentle slope not exceeding 5° is the best. If slope exceeds 5°, then the nursery bed should be terraced. In western Himalayas, northerly aspect is preferred. At higher elevation it is necessary to minimize the frost damage; shelter of a high forest may be available to avoid damage by high winds.

Slopes facing south are much warmer than those facing north, so at high altitudes, above about 1200 m a southerly aspect is to be preferred. A nursery should not be sited in the shadow of nearby ranges of hills. At low elevations in the hot areas, a north facing slope is preferable. Steeper slopes will have to be terraced and on very steep slopes it may be difficult to make terraces wide enough to accommodate normal nursery beds of one meter in width plus paths on each side to allow access to the beds. Steeply sloping nursery means that labours spend a good deal of energy climbing up and down slopes. Therefore, this type of sloping site should be avoided as far as possible.

**8. Exposure to winds, frost, hail & flood:**

The behavior of local winds can best be known from local people. Swift and stormy winds are harmful for nursery. Dust particles carried by wind get deposited in nursery beds and poly bag stocks and damage the young seedlings. Moisture loss is rapid in windy locality. Plants will develop stunted growth.

In the hill valleys are less windy than high mountain slopes. But at the same time very deep valleys without outlet for wind may tend to stagnate wind thus making it worse in quality and quantity of oxygen. Therefore, it is advisable to avoid such sites too.

In the plains, nursery should be established where there is forest cover around the site so, that windstorm gets deflected from tree cover. However, it should be seen that shade does not interfere with the growth of the seedlings. In the plain hurricanes and tornadoes often leave a path of destruction. They result due to high wind; rapid collision between warm and cold air during summer. This is the area which has the experience of such occurrences should be avoided altogether.

Frost is the worst enemy of young tender seedlings. Therefore; it should be ensured that forest nurseries should not be established where there is occurrence of frost. Frost hole area should be avoided. At high altitude, sites, which are particularly liable to frost damage, should be avoided. These include valley bottoms and other sites where the down ward flow of cold night air is obstructed either by the topography or by a dense belt of trees below the site. Forest occurs during October, November, and December in temperate zones. In plains frost may occur during late December to 15$^{th}$ of February. Some species are frost hardy and many are frost tender. If it is unavoidable to establish a forest nursery on a site which is frost prone, adequate protective measures should be taken against frost. The seedlings of some species which remain in the nursery during winter are green watle, deodar, silver fir, kail, spruce, Mango, Neem, Bakaino, Harro, Barro, Bamboo's etc. can be provided with cover of poly sheets or thatch during clear winter nights.

For the selection of site of forest nurseries, it should be enquired from the inhabitants of the area that the area does not experience hail. However, increase of moderate hailing the plants can be protected by providing ani-hail nets and thatch sheds.

As far as possible, hail prone area should be avoided. Unlike frost hail occurs during summer.

Hail is formed when falling raindrops pass through low temperature zone in the sky. The liquid drops suddenly solidity and develops into sleet or hail. Sometimes, hail or sleet pellets are tossed upwards due to wind currents and come into contact with liquid raindrops and collect water coating. This gets frozen again and falls on ground due to its weight with impact and hit hard the ground objects. This causes heavy damage to crop and tender plants. Such phenomena reoccur every year in certain zones. Such hail prones areas can be ascertained from local people and metreological department.

For obvious reasons nurseries should never be established on sites where there is a danger of flooding.

**9. Transport:**

Transport of the planting stocks from the nursery to planting sites should take least time. If possible, a motorable road should be constructed into the nursery to transport materials and seedlings. It may be necessary to construct a short road to connect the nursery to the main road and should be usable in all seasons of the year.

If plants are to be taken away in tractor trolleys, there should be space in the nursery for tractor to turn around. That means wider roads and wide space along the outer periphery of the nursery.

**10. Labour supply or availability:**

Nursery should be selected where adequate labour can be obtained easily throughout the year even at the time of agriculture, and should be preferably near the village or taungya village which can help to labours come on work and back to home in short time. Selecting the site of nursery near village is also likely to increase public awareness of forestry work.

In large nursery, hutments should be constructed in a corner of the nursery for labour, the mali inchorage must live in the nursery.

**11. Availability of land:**

It is important that the site chosen for the nursery, should be enough land to raise the number of seedlings needed. Ten thousand seedlings in standard containers need about 25M2 of standout beds. This area should be doubled to allow for paths between the beds and tribled if the nursery is on a terraced land to allow for a path on each side of the bed. If the seedlings are to remain in the nursery for more than one year, the area will need to be doubled again.

In addition, space will be needed for seed beds (normally 10% of the area of the stand-out beds) provision will also be needed for buildings, thatch huts, water tank, soil shed, glass house and drain etc.

If stumps (root shoot cutting) or naked or bare root plants to be raised, larger area will be needed. For bare root plants, one square meter area will be needed for 125 plants. Thus 10,000 seedlings will need 80M2 of bed space. The area needed for stumps is approximately the same or a little less.

Note: - It is important to bear in mind that natural blanks should not be selected for siting a nursery.

**12. Aspect:**

In hilly area aspect plays an important role in the selection of forest nursery. In the lower hills northern and eastern aspect are congenial where as in higher hills above about 1200 m. southwestern aspect is preferable. The slope of southern; south and eastern aspects to be avoided as they will be causing frost problem during winter. At low elevations in hot areas a north-facing slope is preferable.

**13. Proximity to forest quarters:**

Success of nursery work depends a close frequent and strict supervision; hence proximity to forest (range) headquarters is desirable.

## Necessary Basic Things, Machinery Tools and Equipment:

1. House- soil shed, labour shed, office and store.
2. Fencing materials.
    i. Barbed wire, mesh wire
    ii. Wooden or R.C.C poles.
    iii. "U" nails
    iv. Hammer
    v. Wire pooler, strainer or cable pular or iron rod hook
    vi. Coaster, Enamel paints.
    vii. Plain nails.
3. For surveying – prismatic compass, plaintable with accessories abneyslable, measuring tape, ranging rod, arrows etc.
4. For bed preparation
    i. Spades, (small & large), pick axes
    ii. Wooden hammer
    iii. Ropes, cotton or steel tape
    iv. Wooden pegs
    v. Shavels, Khurpa, sickle, axes
    vi. Wooden planks, bricks, stones, split bamboo's etc.
5. For house – Thatch, weeds, leaves, thakal, Bamboo's, polythene sheet, wood.
6. Iron or wooden shade frame.
7. Water cans, polythene pipe, sprinkler, tube well, for irrigation
8. Sprayer – for irrigation of small seeds sown in beds or seed trays and for spraying insecticides.
9. Polythene bag or tubes – for soils filling and transplanting or direct seed sowing.
10. G.I. net for sieving sand and soil.
11. Wooden seed box or metal or plastic seed tray for seed germination and for transporting seedlings.
12. Thick poly bags, canes, container or glass jar far storing seed.
13. Small metal sieves and Naglo- for sieving and winnowing of seeds.
14. Cutting plier, sharp knife, bill hook- for branch and root shoot cutting.

15. B.H.C. powder, potash, Metacine, Malathene and other insecticides, fungicides and pesticides.
16. Forest topsoil, coarse and fine sand, compost, chemical fertilizers, small crushed or round gravel.
17. Wheel byerer, Basket etc.

These above mentioned things should be arranged for successful operation of nursery.

## 2.4 Design and layout of nursery:

**1. Survey and demarcation:**

After the determination of the type and nature of a nursery the available land should be surveyed, mapping and demarcated so as to avoid any legal complications. After the survey, the area should be calculated and boundaries should be demarcated and permanent boundary, pillars should be constructed and area should be properly fenced according to the requirement game proof\ cattle proof\ deer proof etc. on the map the layout plan is drown-showing fence, nursery sheds, water supply, and arrangement of beds, roads, path and cross Paths, channel and main entrance etc.

**2. Clearance of site:**

All trees and bushes growth in the area should be felled. The stumps should be uprooted. The felled materials and the roots should be removed from the site. The big boulders and stones if any should also be removed along with the debris.

**3. Lay out and construction of terraces:**

Nursery layout will vary according to site. The type of plants to be raised the facilities to be provided and the topography of the site. In low hills and high hills the layout should be given across the slope i.e. along the contours. Height of the retaining wall to be constructed depends on the slope of the area.

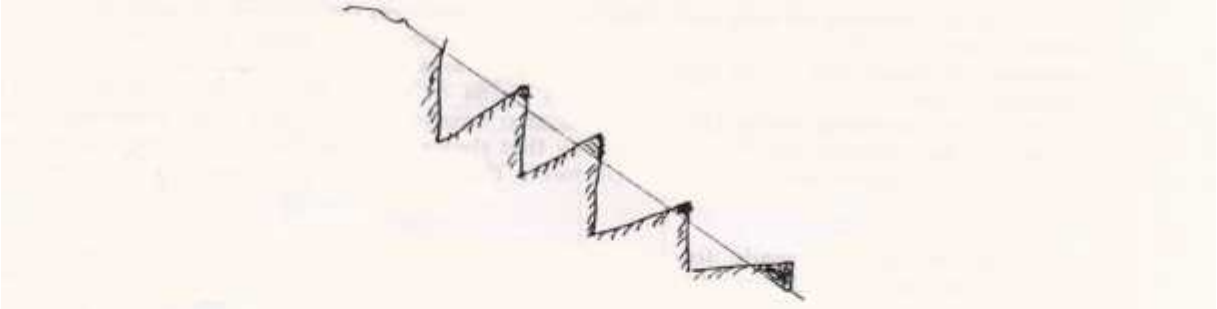


Fig 1 Profile of Bench terraces in hills

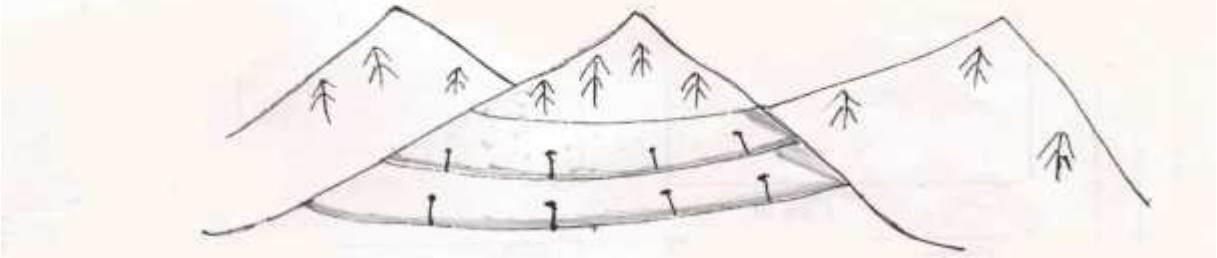


Fig –2 View of Benech terraces in hills.

Gentler the area lesser the height. However, it should not be more than one meter so as to accommodate 2 beds 1 m. width each. In plains where the area is almost flat there is no need of construction of terraces but the layout should be given so as to prepare the beds from east to west direction. If possible the beds should be oriented from east to west to provide better shade against the midday sun and frost in night.

**4. Leveling of terraces:**

After the construction of terraces and layout the next significant issue is to level the terraces. This should be done by cutting of the slopes and refilling the cut earth. Refilling can also be done by importing fertile soil from the forest. The leveling should be done in such a manner that there is light inward slope so that maximum moisture is retained, the soil used for refilling the terraces and leveling should be free from stones, gravel, pebbles, roots, twigs etc preferably the soil should be sieved before refilling.

**5. Construction:**

After cleaning of an area and construction of terraces the outline of beds, buildings, sheds, storage tank etc. should be set out using pegs and lines and then necessary construction made.

## 2.5 Nursery costruction:

As far as possible the nursery area is to be divided into a number of rectangular blocks separated by permanent paths or motorable roads 4 m. wide. Each block by constructing paths 1 m. wide and also smaller 0.6 m. wide between beds. Irrigation channel may be located in a way that they

run along the permanent inspection paths, with the main water channel following the boundary of the nursery as shown in fig. 3.

In the nursery made for extensive mechanized plantations, there should be provision for wide roads on which tractors with trailers can play. Thus each nursery bed should have a tractor road on side of its length and on irrigation channel on the other. In the other words there should be a tractor road after every two beds so that polythene bag plants be loaded from the bed directly o the trailer without any difficult.

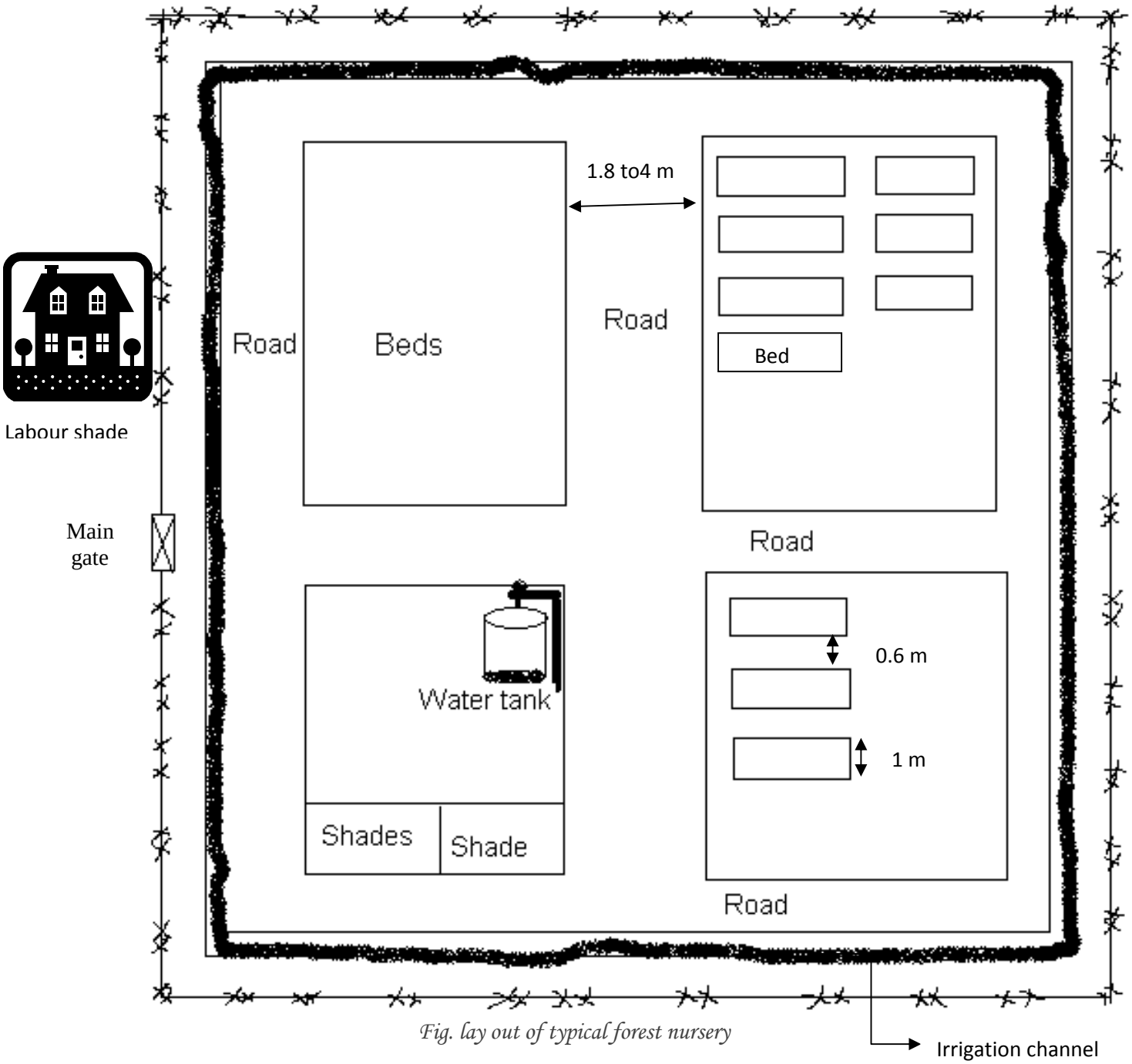



*Fig. lay out of typical forest nursery*

As shown in fig.3 the beds should be laid out with their length in east west direction. So, they can be shaded against frost and sun. Beds should be 1-1.2 m wide and the length of beds should be 5m, 10m, 15m, and/or according to land situation. The paths between beds should be 60 cm. wide as these are useful for inspection, weeding, irrigation and pricking out of seedlings etc.

The water storage (overhead or below the ground) tank should be constructed inside the nursery near main tap or overhead tank should be established. The size of water storage tank depends upon the number of seedlings to be raised. A soil shed, small glass house/plastic house for seed germination under temperature and humidity control. Store house and office outside the nursery (or if possible inside the nursery).

A drainage system may need to be prevent damage from heavy rains, this will be especially necessary on steeply sloping sites where drain should be constructed along the top edge and side of nursery. If drains have to be laid in slopping land, they should be formed in steps. That is they should be divided into short lengths of gentle gradient separated by almost vertical steps, faced with stone or brick masonry.

## 2.5 Types of Nursery beds & their preparation:

A name given to beds on the basis of their nature and practice is done.

***According to the moisture requirement of the species, beds can be of three type;***

### 1. Raised beds:-

The seed beds which are prepared above the ground or path level is called raised bed in heavy moist area, which are liable to be water logged, raised beds may have to be prepared. Raised beds may have to be prepared 15 to 20 cm. above the ground level and where there is heavy moisture and the roots of seedlings require well drained soil and constructed by a line of bricks, stones or bamboos/split bamboos. This prevents their edges from being eroded away during the rainy season or by irrigation or outside water from seeping into the bed. The species which are commonly raised on beds are Deodar, Kail, Spruce, Fir, Robina, Walnut, Bird cherry, Ash etc.

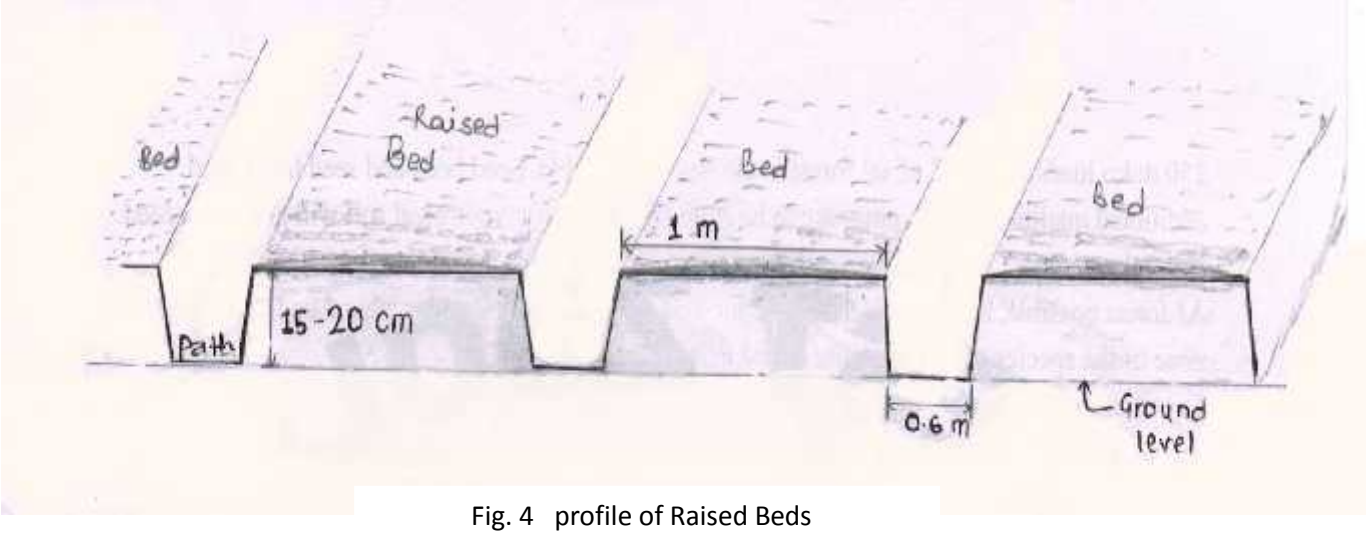



Fig. 4 profile of Raised Beds

## 2. Sunken Beds:-

The seed beds which are prepared below the level of the ground or path are known as sunken beds. These types of beds are prepared in dry areas where scarcity of water for irrigation means water conservation is needed and is necessary to collect as much moisture as possible. For this purpose, the beds are made 10 to 15 cm. below the general ground level or the inspections paths. This type of beds are used are used for raising stock through vegetative propagation like cutting of popular, Sissoo, Mulberry, Willows, and Bamboos off sets. Besides these *Acacia nilotica, A. benthenwii, Prosopis juliflora* etc.

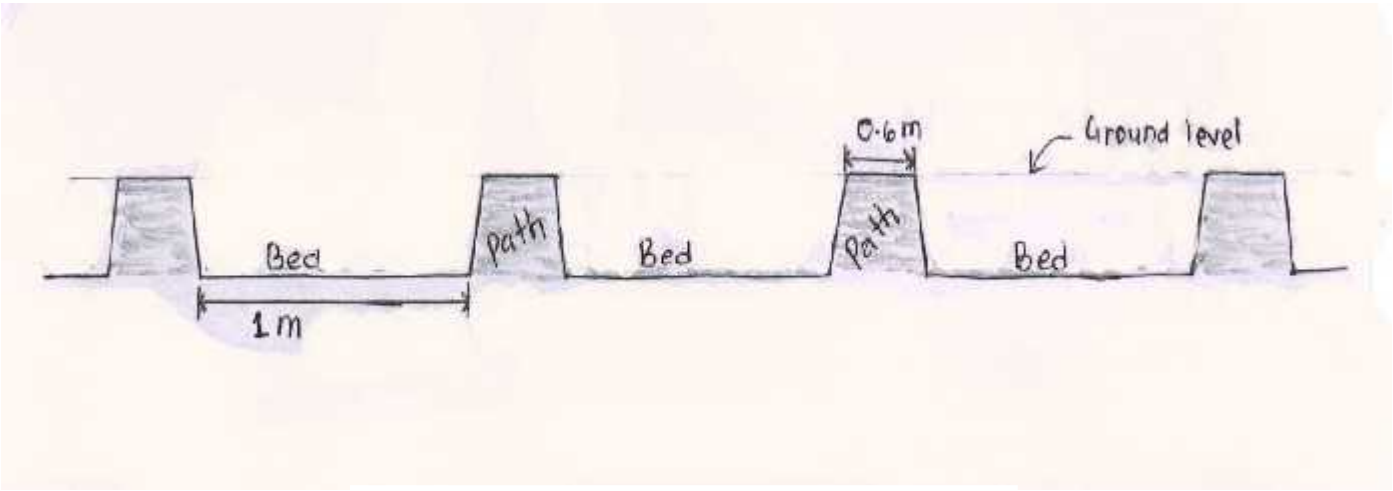



Fig. 5 profile of Sunken Beds

## 3. Level Beds:-

Level beds are commonly used for raising seedlings of Tuni, Eucalyptus, Ritha, Terminalia, Siris, Grevillia etc. These species cannot tolerate standing water; their water requirement is also moderate.

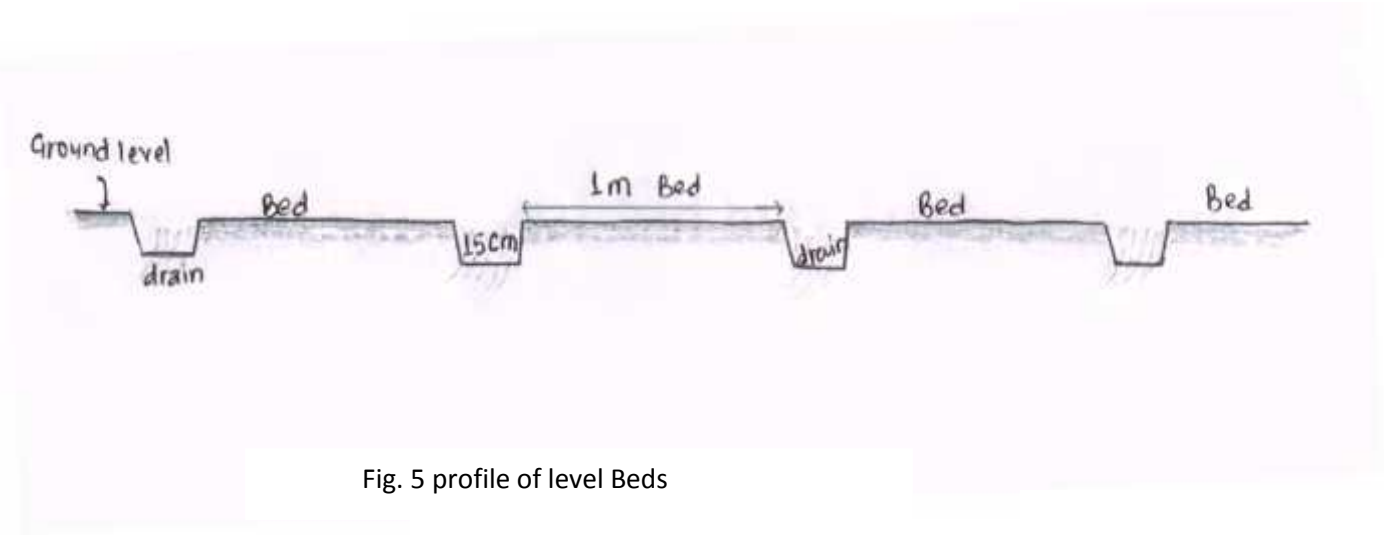



Fig. 5 profile of level Beds

***According to the practice, beds can be of three types. They are;***

### 1. Seedling beds:-

A name given to beds in which the seeds germinate after sowing. The young seedlings remain in these beds for a short period of time after which they are usually picked out and transferred to transplant beds or standout beds.

### 2. Transplant Beds:-

These are beds in which pricked out seedlings are raised after they have been transplanted from the seedlings beds. In transplant beds,the sedding are spaced out of more evenly, than compared to seddling beds in which the germinating seeds may or may not be so evenly spaced out.

### 3. Standout Beds:-

## Culture of seed beds

After aligning(staking) the actual beds, these should be dug 30 to 45 cm deep, excavated soil should be roughly cleaned of stones, roots, and other unwanted materials, then the dugout soil should be allowed to weather for 1-3 months. Beds may be raised, sunken or leveled by removing or adding soil from the path between the beds. A light camber should be given in order to ensure drainage and the side should covered by the support of planks, stones, split bamboos and bricks as mentioned previously.

## 2.6 Methods of seed treatment:

The success of artificial regeneration by largely depends upon quick and uniform germination. The 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. Therefore it is essential that the seeds should be treated to hasten germination. The following are various treatment that hasten germination and, therefore, one of them which has been found to be the most appropriate by repeated trials for the species in question, may be given;

1. **Weathering:** weathering means exposing the seed to sun, wind and rain to crack its hard coat. Thus the seed is spread out on bamboo mats raised above ground to be exposed to sun, wind and rain during the monsoon until germination is seen to be just starting. Then seed is dried in shade and bagged for sowing in the following rainy season.

2. **Water treatment**: In water treatment, water is used to hasten germination. Water may be cold or hot and seed may be soaked in water or alternately wetted and dried.

   a. *Soaking in cold water for 24-48 hours before sowing:* this treatment is applied for medium sized dry seed. E.g. Chirpine, Leguminoceae spp.

   b. *Soaking in boiling hot water:* The water is heated in a container and when it starts boiling, the container is removed from fire and seed is dropped in it and then allowed to cool. This treatment is used for hard coated seeds e.g. Oaks and Chestnut.

   c. *Alternate wetting and drying:* In this method, the seed is alternately wetted for some hours and then dried. This method is applied to Teak in one of the following ways;

(i) *Nursery bed process:* A raised nursery bed is covered with sand 5 mm. thick and seed is spread on it. It is then covered with grasses and water sufficiently to wet seed and the sand. After 12 hours the grass is removed so that seed is exposed to sun and dries. This continues for 2-3 weeks when the seed starts germinating. The germinating seed is removed to another seed bed to raise seedlings for making stumps.

(ii) *Pit process:* In this process a pit about 0.8 m deep and 1-2 m. square is dug grass or leaves are spread in bottom, then seeds are spread over it, then green cow dung is spread and again covered with grass and this process continue upto the upper level and remaining 15 cm pit is filled with earth, alternate day irrigation is given through holed bamboos pipes placed in places in the pit or direct on pit. The seeds are kept in pit for 7-10 days. The pit is then opened and treated seeds are sown in bed or in containers. Heavy watering must not be done.

3. **Passage through animal body:** Some seeds, e.g. *Acacia nilotica*, *Prosopis juliflora* and *Santelum album* germinate quickly if they are passed through the digestive system of the animal or poultry.

4. **Mechanical treatment:** mechanical treatment refers to the mechanical cutting or filling of the hard impervious coat of seeds so that moisture may reach inside. This method is not more practicable and economical.

5. **Chemical treatment:** soaking in various chemical solutions often the hard coat of seeds and renders them permeable to water. The solutions used successfully in certain cases are lime water; dilute alkali or acid solutions (5 to 15% for 1-24 hrs), conc. $H_2SO_4$, (about 4 times the volume of seed for 15 minutes to 2 hrs), salt solution, e. g Sulphate of magnesium etc. But the method requires more experience in this field.

6. **Scorching or fire treatment:** It has been observed that a fire through the teak forests stimulates germination. Therefore, the teak seed is sometimes spread on ground on a layer of leaves and given a light burn. This method is difficult to control. It is not being used now.

7. **Stratification:** In this method, the seed is spread in layers 1-2 cm deep alternating with layers of sand, peat, or charcoal about 5-7 cm deep in boxes or basket, stored in pits dug in the ground. The boxes and baskets can also be stored in cold damp cellar. The method can be used in higher hill forests.

8. **Fermentation:** In this method the seed is spread on ground covered with grass which is kept moist. Fermentation is induced by adding inoculums from a cattle shade or drain. The bacterial action is allowed to continue for about 2 months when the seed is ready for dibbling e. g Teak on dry zone.

## 2.7 Seed testing & Seed certification:

**Seed testing – Viability:**

As the success or failure of artificial regeneration work depends on the quality of seed, it is necessary that seed is tested before use. Seed testing offers two advantages. It prevents loss in respect of money, labour, time and effort resulting from failure due to bad seed. It helps in finding out the real cause of failure by eliminating an important cause. Though seed testing has not been given the attention in the field it deserves. It is hoped that with the large scale plantation work being undertaken, it will be adopted as a routine practice by field staff. Seed testing is done with the following objectives;

1. Determination of genuineness: The first thing to investigate is genuineness of seed; whether the seed is really of the species which is to be raised. If there is any doubt about the identity

of seed received from outside it should be compared with the description and photo given by Troup in ' Silviculture of Indian trees ' and weight, size and other details or any available authorized document or get it identified by an expert botanist/forester.

2. Determination of purity: The most seed may be genuine, even than it may have some adulteration of some other seed or foreign matter. This would affect the success of plantation. For this purpose (purity) a weighed sample of seed is clean of all foreign matter by winnowing and hand picking and cleaned seed weighted again. It is expressed as a percentage of the former.

3. Determination of seed viability: This is an important test and should be carried out with great care. The method of testing will however vary with the facilities available, the degree of accuracy required and kind and condition of the seed to be tested. The following tests are generally carried out;

   (a) Direct inspection/ cutting test: For this test, a representative sample is taken from the seed to be tested. The exact number of seeds required for the test is counted and the spread out on table, each seed is then cut open. All seeds which are hollow, insect eaten, mouldy, raniced, shriveled up or otherwise obviously bad are excluded as unviable, the rest are viable.

   (b) Physical test: Light and hollow seeds are infertile, they can be separated by winnowing or submersion in water.

   (c) Chemical test: Use of chemicals to determine the viability of the seeds. The most important chemical test is called "Vital staining", Indigo-carmine in 1:1000 or 1:2000 solution is reported to be most useful separate dead & dying. Another chemical test is called "Bio-chemical method" as it ratory activity, to reduce certain chemicals and to produce distinct colour changes in living cells of the seed.

   (d) Germination test: The test in which the seeds are actually induced to germinate and commence growth is called germination test. It is the most dependable test for assessing the viability of seeds. Though a large number of appliances have been devised for the purpose but the following are enough to serve the purpose;

      i. <u>For medium sized dry seeds</u>: A porous fire clay plate with 50 to 100 depressions standing in a dish of water and with a glass cover to maintain a moist atmosphere. One seed placed in one depression and as it germinates it is removed keeping a count of such removal.

      ii. <u>For larger seeds</u>: A shallow wooden box or an ordinary flower pot filled with clean seed saw dust or light soil. Vermiculite mica is also used as a medium as it has many advantages.

(e) X-ray techniques: In this method the seeds are first soaked in water for 10 hours at room temperature and then in a solution of Barium chloride for 1-2 hours. While barium chloride penetrates the dead tissues through a process of diffusion, it can not penetrate in living cells due to semi-permeable nature. The seeds are then washed for 1-5 minutes in order to remove Barium chloride from the surface and then dried in a thermostat at 70˚c at 25 cm and exposure time 2 second on 10-15 rontgen ray. An embryo is considered viable if it is free of impregnated not more than 25%. The main advantage of this technique is that the seed can be used even after the test.

## Seed certification:

The market value of seed is directly affected by results of purity and germination or viability test. Other factors such as scarcity, certification class, quantity and special processing may also influence the value of a seed lot. Because germination or viability test results are only estimates of the seedling potential for a lot, some interpretation of test results is usually necessary. Practices commonly accepted in seed transactions are described briefly below;

Interpretation test results:

Because dormancy varies among lots, seeds of some species are often tested for germination both with and without prechilling. Generally the highest value obtain in such dual test is accepted as indicative of the germination potential for the seed lot. Test results that reflect full viability of the lot, such as tetrazolium staining and excised embryo, may indicate higher potential than is indicated by germination test because the latter excludes dormant seeds and abnormal seedlings. Results of cut seed test also tend to be higher than germination test because they determine it healthy appearing endosperm and embryo are present, but not actual viability or germination potential. Neither viability nor germination test results indicate precisely how a seed lot will perform under various field conditions, but the results of laboratory germination tests have generally been considered the best indicator. Rapid viability and x-ray tests are becoming more reliable and when they are properly performed and evaluated results may deserve equal consideration with those of germination tests (Hardin 1981).

Firm under germinated seeds often remain after completion of a standard germination test. Testing laboratory reports separately the percent germination and the percent firm ungerminated seeds. It is possible that firm germination seed would have germinated if given more time, longer prechilling, or more suitable germination conditions. In seed transactions, the accepted potential of a seed lot may be the percentage germination or the sum of the percent germination and the percent firm under germinated seeds.

In addition to providing the basis for pricing or sowing a seed lot, germination test results provide other useful information. Rate, vigour and uniformity of germination and duration of the germination period are helpful indicators of the seed quality and response. The amount of firm under germinated seed or deteriorated seed may signal the need for a longer or shorter chilling period. Seed analysists and seedman are good source of assistance for interpretation of test results.

Pure live seed:

Pure live seed (PLS) = (percent germination or viability/100) x % percent puring

Price per kg (PLS) = price per kg for impuresud / (percent pure live seed / 100)

The number of pure live seed per kg is calculated as;

Number PLS per kg = (number of pure seed per kg x percent germination or viability) / 100

**Labeling & Records:**

- Name of species (Scientific/ Latin name or Nepali name)
- Family name
- Date of collection
- Place of collection
- District/VDC
- Zone

Additional information:

- Altitude
- Aspect
- Number of trees from which the collection was made
- Area from which the seeds are collected in hector
- Average size (height, diameter) of the tree
- Soil type, general vegetation type
- If from the plantation – the date of plantating.

## 2.8 seedling production and management:

Plants can be propagated sexually or asexually. The basic difference is the process of fertilization that occurs in the first but not in the second.

Asexual propagation, in turn takes two forms- Apomixis and vegetative propagation. Apomixes is propagation through the development of one on gamates (the ovule) without fertilization or off cell without reduction.

Vegetative propagation is propagation from well differentiated vegetative parts.

Propagation methods:

1. Natural method
   A. From seed
      - In the forest
      - In the nursery

B. From coppice – mainly in the forest and/or in the nursery.

2. Artificial method
    A. From seeds – seedlings raised in nursery
        i) In an open bed
        ii) In container

**Soil preparation**: - Soil preparation involves the following steps;

- The soil is dug up to a depth of about 40-70 cm. All stones, roots etc occurring till this depth are dug out and removed. Digging may be done either manually or mechanically incase of large nursery.
- The soil is sieved through a fine wire netting so that all coarse particles are removed.
- The fine soil is thoroughly mixed with good farm yard manure. Aldex may be added if there is danger of attack by white ants.
- After sometime, this mixture of soil and farm yard manure is again filled back into the pits.
- If the soil is heavy, burning of dry grass and shrubby materials, tend to reduce weed growth.

**Bed preparation**

Size of beds: - The size of nursery beds may vary from-

- Species to species.
- Locality to locality.
- Purpose for which the nursery is being established.
- Length of bed 5-20 m.
- Width of bed - 1m.
- Path 0.5 to o.65 m.

**Sowing of bed**

- Broadcast sowing
- Dibbling sowing
- Drill sowing.

**Quantity of seed**

The quantity of seed to be sown in each bed depends upon;

- Weight of seeds
- Size of the bed
- Spacing
- Plant percent

$$W = (A \times D \setminus P \times N) \times 100$$

Where, W = weight of seed needed in gm.

A = Area of the bed in $m^2$

D = Number of plants needed per $m^2$

P = plant percent

N = Number of seeds in each gram.

However, in general practice, between 1.5-2 times the quantities of seed should be used in case of drill sowing and 3-4 times in case of broadcast sowing.

**Time of sowing**:- The time or season of sowing depends upon the following factors-

- Time or season of ripening of the seed
- Rate of growth of the species which is being raised
- Size of the plant to be transplanted
- Climatic condition of the area or locality.

**Covering the seed and seed beds:**

After seed sowing immediately seed should be covered with soil/ sand/ ash. In case of danger of the seed being eaten by birds, rodents, pest etc. the under mentioned protective measures may be adopted.

(a) Application of insecticides:- Alderine, Aldrex, B.H.C, DDT and grammaxine etc. may be mixed with the soil while preparing the nursery bed. Very often insect repellent may be mixed with the seed eg. Red lead, kerosene oil and camphor liquid repellent may be rubbled thoroughly on to the seed.

(b) Covering the seed bed/ mulching:- The seed bed may also be covered by thorns and dry bushes, to protect the underlying seed from being devoured by birds and rodents. For example- Deodar seed.

Seed beds are also covered with grass, dry leaves, and pine needle to conserve the moisture and to hasten germination called mulching.

**Irrigation:** Water forms an important pre - requisite for the growth of plants. Light irrigation is needed even by the hardiest species, particularly when the seedlings have to remain in the nursery during the long and dry summer months.

Irrigation is best done during afternoon, but in places where there is a danger of frost this may be carried out in late mornings. Weeds should be removed before watering. In case where the

seedlings are densely crowded, thinning should be done. If possible addition of a little acetified, formaldehyde or 4% copper sulphate can be used in irrigation water to prevent damping off.

Nurseries may be irrigated by the following methods:

Cane irrigation:

1. Percolation: In this method, water is allowed to stand round raised narrow beds so that moisture percolates to centre of bed from sides.
2. Automizer irrigation: An automizer is a pump by which moisture is applied to the seed bed in the form of water vapour.
3. Sprinkler irrigation: In this method, water comes out in the form of small jets from pipes which are laid out all over the nursery bed. Very often this arrangement resembles that of a a fountain with jet of water first going upward and then falling on to the bed.
4. Flood irrigation: This method involves flooding of the seed bed water. It is normally adopted in dry/arid areas with sunken beds.

**Weeding:**

By the time seeds being to germinate, there also come up a host of weeds on the seed bed. They offer competition to the struggling seedlings for light and food, hence have to be removed from time to time, or else they may lead to the death of seedlings. Weeding thus, is a very important operation, which is not to be delayed or ignored under any circumstances.

**Protection of seedlings against:**

- ♣ The sun: Young seedlings of certain shade bearing species may need shade against the excessive heat and insolation of sun during the pre-monsoon period.
- ♣ The frost:
- ♣ The rain and hail:
- ♣ The fungus: Pythium, phytopthora, Fusarium and Rhizoctonia spp. are mostly attacked in seedling can be controlled by using fungicidal spray.
- ♣ The insect pests: Beetles, cockchafer, cricket are the bad enemies for seedlings, may be controlled by using Game B.H.C. dust and other suitable and available insecticides.

**Pricking out and transplanting:**

When the seedling of certain spp are kept in the nursery for a period less than one year, they should be pricking out from the seed beds and transferred to the transplant beds or planting into the containers. If root shoot cutting or stump is to be prepared for planting, spaced out or transplanting is essential which have to be kept in the nursery for more than one year, pricking out is carried out each year.

**Hardening off:**

This is a process in which seedlings due to be planted within a short period of time are hardened off or conditioned for field conditions by slowly reducing water, shade, and shelter etc.

# UNIT 3 PLANTATION TECHNIQUES

**3.1 Appraisal of planting sites and its protection**: - For all kind of planting needs appraisal of sites before planting. But especially industrial plantation development requires large area of land. Therefore, land availability is important. Following things are required to assess.

1. **Land capability**: Land capability part of modern land use planning is the idea that is an optimum use for a parcel (An extended area of land) of land. The 1st stag in evaluating land and preparing a land use plan is to gather data to classify land according to what it may be able to grow- many different kinds of information about land and land use to be used together through the emerging technologies of Geographic information systems(GIS). We can get readable account of GIS. Land capability, also called land suitability (FAO1984 b), is primarily concerned with the potential biological productivity of land and this is determined by four main components of the environment
   - ✓ Climate- hot, cold, humid, dry.
   - ✓ Local topography.
   - ✓ Steepness, exposure.

     Which caused local variation in climate and disposing of soil type

**A. Climate**: - Climate is the dominant influence on land use in the tropics. But it is not easy to determine what are the most useful descriptor of climate for classifying the productive potential of land. Several system of climate classification has been developed by Thornth Waite (1948), Paterson (1956); they mostly apply at the regional level but tend to break down level, groping into similar climatic zones is a practicable compromise. This has been done in South Africa to delinate silvicultural zones indicating suitability for afforestation (Poynton 1971). These approaches are referred to as Bio-climatic zones. When we incorporate soil and other site data to relate to crop production potential as "Agro-ecological zones". Where exotic species are introduced to a new location, such classification are some guide to suitability, but more detail study of potential

- Evapotranspiration
- Seasonality of rainfall
- Temperature- maximum & minimum
- Occurrence of forest etc.

are invariably necessary for species to be matched closely with site. E.g. desert sand of northen Australia yield very little while, the same latitude the coastal sands of quins land support productive *Pinus caribea* plantation. The difference is simply due to occurrence of sufficient rainfall. It is sometimes possible to overcome the limitation of climate. It has been used to establish tree plantation in arid regions; also shed trees and shelterbelts modify microclimate, often making possible or enhancing growth of crop such as coffee and coca.

**B. Topography:-** The influence of topography on land capability is best seen in the increasing restriction of possible alternative uses as terrain becomes more broken and rugged,

- Steep slopes/drainage
- Ridge-top exposure
- Water logging in gullies
- Ground rocks 7 boulders

**C. Soil:-** Soil fulfills three essential requirements for tree growth;

- Supply of moisture
- Nutrients and
- Provision of mechanical support

Besides these

- Inherent soil fertility
- Physical condition
- Rootable depth are the consideration

However, there is no one optimum soil since different species grow best under different conditions of nutrient supply, moisture condition, acidity etc.

Soil survey for land evaluation is complex, but there is distinct benefit for forestry. The objectives of any survey are essentially to assess both the three functions of soil noted above and more general features affecting its management;

1. Rootability and rootable volume
   - Depth of soil to impeding layer-bed rock, stone line, water table
   - Quantity of rocks and boulders in the soil
   - Soil texture- especially the proportion of sand, silt, clay & organic matter
   - Compaction and bulk density

2. Nutrient supply (fertility)
   - Concentration of plant nutrients in extracted soil solution
   - Cation exchange capacity (CEC)- how well nutrient ions are held and stored in the soil
   - Soil acidity- pH
   - Organic matter and carbon to nitrogen ratio (C/N)
   - Geology of under laying rock or parent materials

3. Moisture supply:
   - Soil moisture content
   - Fluctuation in depth of water table.
4. Risk of soil erosion

**D. Existing vegetation or Stages of succession:-** Seral or climax

**E. Land use:**

**F. Land and tree tenure:**

**G. Customary ownership:**

- Private ownership
- State control

**H. Impact of other land uses**

**I. Population density**

**J. Geographical consideration**

**K. National land use policy**

**L. Determination of suitable species & planting stocks (plant types) of planting**

Points should be considered:-

- Soil working / pitting
- Transport facility
- Labour availability
- Plot lay out / plotting-not more than 50 or 100 ha. plot

**Protection of planting sites**:

- For animal damage- cattle proof fence
- For porcupine- porcupine fence
- For deer- deer proof fence
- Rhino proof fence

Types of fencing:-

i. Barbed wire fencing
ii. Gavion net fence
iii. Stone wall fence
iv. Brick wall fence, brick net ring fence
v. Trench fence
vi. Live hedge fence
vii. Bamboo ring fence
viii. Electric fence
ix. Trench fence

Protection from weed competition:- regular weeding or use weedycides.

Protection against fire: - construction & cleaning of fire lines.

Protection against insect, pests & diseases:- spray insecticide, pesticides & disease control medicine.

**3.2 Plantation design: -**

Plantations are ordered and regular in appearance because trees are planted in lines and boundaries and internal breaks are often straight. In plantation design there are three aspects need to be considered at the same time;

- Shape:- Rectangular, square, triangular and Quincunx.
- Line of communication: - Road, path and access.
- Lay out and internal sub-division:- Block, compartments based on administrative unit.

Blocks are formed based on administrative unit- shape and size of area to be planed, objectives of plantation and block is sub-divided by compartment within a block. A compartment is the "address" to identify part of a forest and a operation unit for most kind of work (inventory, silvicultural operations, harvesting etc.). with the whole compartment treated at the same time and usually in the same way. Normally compartments are bounded / separated by a road, path, and track or fire line, fire block. Their size range from 25 to 100 ha., but 25-50 ha. is probably about average.

**3.3 Choice of species: -**

The success of an artificial regeneration/plantation depends upon the correct choice of species; slight error in this regard may result in failure of the plantation and consequently loss and wastage of money time. Choice of species depends on the following factors.

1. Climate:- macro & microclimate
2. soil types and condition:

- Lime reach soil
- Stiff canker clay

Clay soil: - i. liable to water logging
ii. Not liable to water logging

- Sandy soil:-
- Silty soil:-
- Soil with high concentration of soluble salt.

3. Topography: aspect, altitude
4. Plant indicator
5. Stage of succession
6. Objective of management
7. Consumer's requirement
8. Growth rate
9. Ease of establishment
10. Availability of indigenous/exotics species
11. Cost of plantation
12. Effect on site

**3.4 Methods of site/ground preparation: -**

Successful planting often depends on measures such as

- Reduction of competing vegetation
- Removal of physical obstacles
- Drainage and water towards or away from the planted trees.

Control of competing vegetation is especially important because many planting sites are already crowded with pre-existing vegetation. Unless a distinct vacancy is found or created in a growing space it will be difficult for a planted tree to survive or grow satisfactorily. Site preparation as a means of controlling competing vegetation is usually done as a separate operation. However, planting sports can also be prepared at the same time as a planting by spot application of herbicides or scalping, which is the scalping of competing vegetation from the planting sports with hand tools. Scalping is moderately effective against thin grass or very low shrubs and can be done with the grub hoes sometimes used in planting. The more important treatments for site preparation are:-

- Cleaning and disposal of slash
- Slash burning
- Ploughing / harrowing
- Pitting / strip soil working ( in case of sowing in strip), mechanical treatment
- Mound construction
- Trench construction
- Patch soil working
- Treatment of the soil
    - Fertilization
    - Introduction of insecticides, fungicides
    - Irrigation and drainage

**Objectives of site / ground preparation:-**

i. To reduce fire danger
ii. To enable seedlings and cutting to develop long root system
iii. To enable rainwater to penetrate deeper to that moisture is retained in soil for a long time
iv. To improve aeration of soil
v. To reduce the root competition
vi. To accommodate root system of plants.

**3.5 Pitting: -** Pits are dug for planting. They may be of following kinds:-

(for design and dimensions see L.S. Khanna Principle and Practice of Silviculture page no 335 to 342.)

**i. Ordinary pit**

ii. **Saucer pit**
iii. **Ring pit**
iv. **Ridge pit**
v. **Double trench**
vi. **Trench pit**
vii. **Shallow trench ridge**
viii. **Deep trench ridge**
ix. **Trench mound**
x. **Shelfed trench**
xi. **Strait trench mound**
xii. **Wurli**

**3.6 Spacing: -** Spacing varies with species and in the same species with local conditions. There are mainly two spacing;

- **Wide spacing**
- **Close spacing**

*Following factors govern the spacing:-*

i. **Rate of growth:** Fast growing spp.:- wider spacing
Slow growing spp.:- close spacing.
ii. **Habit of branching:** Species have larger number of branches have close spacing.
iii. **No. of annual rings per centimeter:** Wider ring requires wider spacing, denser wood requires close spacing.
iv. **Height of planting materials:** Tall plants to be planted wider spacing.
v. **Site factors:** Dry and poor soil - close spacing
Rich and fertile soil - wide spacing.
vi. **Inter cultivation:** Wider spacing.
vii. **Market for small sized timber:** Close spacing for short rotation.
viii. **Fruit production as objective:** Wide spacing.
ix. **Cost:** Close spacing increases cost of sowing or planting.

**3.7 Handling of Seedlings: - Handling** of seedlings is important in nursery and plantation sites. We have planting stocks such as

- Naked root plant
- Container plant
- With bole of earth
- Root shoot cutting ( stump plant)

- Branch / stem cutting plant

These above mentioned planting stocks should be handled carefully in nursery, loading on vehicle, trailer and at the time of unloading and placing in transit nursery and distribution of plants in planting pits. Care should be taken that the roots and shoot should not be damaged unless plants will not success or survive due to injury.

### 3.8 Plantation versus Direct sowing: -

After selection of species and site, as the case may be method of artificial regeneration has to be decided. Artificial regeneration can be accomplished either by sowing of seed directly in plantation area or by planting nursery grown seedlings or plants obtained by cutting from nursery.

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

i. The species to be raised
ii. Condition of site
iii. Availability of seed
iv. Cost of raising forest.

**i. The species to be raised:-** Though most of the species can be raised by both the methods. Some of them are Sal, Khair, Siris, Sissoo, Kail, Alnus, *Leucaena leucocephala*, *Cassia siamea* etc.

**ii. Condition of site:-**

- In poor and difficult site- sowing is generally not successful and therefore planting should be done.
- In infertile barren soil
- In places of infected with grass and other weeds
- In place where long closure is not possible due to pressure of grazing
- In the places of eroded soil
- In failure portion of natural regeneration

} Plantation is generally adopted

**iii. Availability of seed: -** For sowing requires large/huge quantity of seed shown, do not develop into seedling due to adverse climatic and edaphic condition. The species which do not produce large quantity of seed every year to be raised by planting.

**iv. Cost: -** As a general rule, the method of artificial regeneration which gives greater success as comparatively lesser cost is preferred.

**Advantages of sowing**:-

- Sowing cost less
- Work is completed soon
- The resultant seedling grows without any disturbance to its roots as happen in planting.
- There is no adverse effect on growth of plants.

**Disadvantages of sowing:-**

- Requires large quantity of seed
- The birds, rodents, animals may eat/destroyed the seed.
- The seedlings mortality is high.
- Required weeding for relatively longer period and more –which becomes costlier.

**Advantages of planting**:-

- Much less quantity of seed required.
- Damage to seed by birds is completely eliminated.
- Sure success of plants.
- Weeding is cheaper.

**Disadvantages of planting**:-

- Planting is costlier than sowing.
- It requires more labour, particularly skilled labour and nursery work too.

### 3.9 Concept of forest fertilization: -

Fertilization has not been used in forest plantation so far to any significant extent; because they were mostly raised on forest land, but as most of them are now being raised outside forest area on marginal soil; application of fertilizer has become very necessary to fulfill the objective of quick and best return. 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. On the basis of experience, knowledge, quantity, time, method of application of chemical fertilizer will have to be worked out through soil analysis, keeping in view that cost of production of timber does not become exorbitant.

Fertilization, drainage and irrigation are intensive treatments of the soil aimed more at improvement of site quality than at preparation for regeneration. The proper conduct of these treatments depends so heavily on knowledge of the complex chemical properties of the soil and their moisture relationship that is logical to refer to work on forest soils and other accounts. Few forest soils provide an optimum supply of the nutrient elements essentials for the growth of trees. Sometimes marked deficiency may exists because of improper

land management in the past or merely because of inherently low natural fertility of the site, the nutrient elements most likely to be deficient are the NPK elements of most fertilizers Nitrogen, Phosphorus and Potassium, in that order of frequency of deficiencies.

It is often possible to make forest trees grow better by increasing the supply of nitrogen. The most common cases in which this does not happen are sites where the supply of water or phosphorus is the limiting factors instead. The most common nitrogen fertilizers used in forestry are urea compounds that yield positively charged ammonium ions, which can be observed in the cation exchange capacity of the soil and are easily taken up by plants. Urea formaldehyde compounds have the advantage of releasing the ammonium slowly, while nitrogen compound can be used, the negatively charged nitrate ions are easily lost from the soil by leaching.

Nitrogen compounds in the forest system are constantly moving to and from the atmosphere or being lost to moving to soil water. They can be very mobile and are lost because of leaching. They can also become unavailable to higher plants through being captured by decomposing organisms in the soil or by being locked up in undecomposed organic matter. This often happens where the soil climate is unfavorable to decomposition. It is sometimes possible to remedy nitrogen deficiency by stimulating the symbiotic and non symbiotic nitrogen fixing organisms (Gorden and Wheeler 1983). Fertilization with other elements sometimes stimulates the nitrogen fixers as does the encouragement of legumes, alders and other plants that support symbiotic nitrogen fixing bacteria.

The cost of artificial fixation of nitrogen for fertilizer in terms of both money and energy is high the effect of given applications are limited to several years, so repeated application can be necessary. However, nitrogen is so crucial in building the proteinous bio-chemical machinery of life that spectacular effects can result from reducing the chronic deficiencies. Fertilization with nitrogen compound alone has become moderately common in the humid part of the country and other forest areas where growing conditions are good and nitrogen may be the most important limitation.

Phosphorous deficiencies remediable by fertilization are common on poorly drained soils. In these and most other cases of phosphorous deficiencies, the problem is that the acid condition of the soil or the other factors causes to much phosphorous to be tied up in unavailable form in compounds with ion and aluminium. Phosphorous can be applied as ground phosphate rock or in more concentrated form. These are not very consumptive of energy in manufacture. Single applications have long lasting effects.

The amount of nitrogen and phosphorous available to plants must be the right amount of one can make a deficiency of the other more acute or even harmful. If a tree has a more phosphorous to form the energy transfer machinery of photosynthesis; for example, it's also needs more nitrogen to build the protein components of this machinery.

If there is opportunity for good nutrient cycling single applications of potassium fertilizer in the forest seem to suffice for very long period. It is not easily lost by leaching but

even leak out of green leaves. Deficiencies have been encountered on easily leached sandy soils, previously subjected to highly extractive kinds of agriculture crops removal in New York state (Leaf & Leonard 1973).

There is no any research has been done in forestry in our country, but there are few cases in forestry in this regard in other countries in which actual benefit has come from fertilization with other elements it is rather surprising that there is little evidence of improvement from adding calcium, magnesium or manganese. The deficiencies of trace elements such as zinc, molybdenum, boron, cobalt and copper are known mostly from a few districts in Australia. Australia is an ancient and strongly leached continent where deficiency of phosphorous and other elements have caused forest fertilization to be much more remarkably successful than in most part of the world.

Forest fertilization is normally done from air. It is usually desirable to avoid fertilizing the forest waters so as to avoid contributing to eutrophication. The materials to be spread are heavy enough that it helps to minimize flying distances. It is also important to be able to load the air craft quickly.

The most cases it is best to restrict forest fertilization to the later part of the rotation. A given amount of fertilizer seems to produce about the same amount of wood regardless of tree size and the given cubic volume put on small trees. Furthermore, the supply of available nutrients is generally greatest just after the destruction events associated with regeneration. Deficiency is most likely to set in after the stands have felled all the growing space and more and more nutrients are getting tied up in living and dead organic materials on the site. Fertilization is done at the time of planting or regeneration only if the deficiencies are very serious, as on recently drained organic soils. Sometimes fertilization of young stands favors the competing vegetation more than the trees. There are other causes in which it is not needed and some in which it induces harmful imbalances between nutrient elements.

**Timing of fertilizer application**:

Fertilizers could be added at any one of four stages in the life of a stand.

1. At establishment: - For maximum response most research indicates that for pine and Eucalyptus fertilizers should be applied within 3 months of planting.
2. During the post establishment phase upto canopy closer when deficiency begin to show.
3. In pole stage fertilizing during early thinning to boost thinning response and generally stimulate growth.
4. As a prefelling application, 3-10 years before felling, to add increment before the end of the rotation.

   Both stages 3 and 4 are largely experimental and not practiced widely though (Millar 1981) suggested late fertilizing (4) especially with nitrogen, may often be worthwhile.

**Applying fertilizer**:

Fertilizer may be applied by hand, from a tractor with spreader, or from an aircraft. Hand application is slow but ensures proper placement of the fertilizer near the tree and, theoretically any area and kind of ground can be covered. Fertilizer placement is important since it must either by too close to cause root burn to the young tree nor too far away to be unavailable during the period before it is leached, washed away, or is permanently immobilized in the soil. At time of planting placement of fertilizer does in a small hole 5-15 cm. from a tree is being increasingly used instead of surface application.

Tractor spreading of fertilizers moderately flat and even ground and is only suitable for strip or broadcast application.

Aerial application is only worthwhile for large areas and where full service facility is available.

Most fertilizers are marked in granule or powder form though some compounds ones containing micro nutrients are applied as a liquid to be watered or on applied as a folior spray. The quantity of fertilizers applied depends on results of fertilizers trial or on the basis of requirement of soil and plant based on soil analysis report. Normally the amount of fertilizer is prescribed in kg for the particular elements or its oxide. If phosphorus is required at 75 kg/ha about 68 gm/tree if planted at 3 x 3m than about 577 kg/ha of rock phosphate is needed, since the content of elemental P in rock phosphate is usually only 13% or 357 kg/ha of triple supper phosphate with 21% elemental P in rock phosphate is usually only 13% or 157 kg/ha of triple supper phosphate with 21% elemental P.

One subject not fully evaluated is deterging the best from for a nutrient element to be applied. For example (Jogo and Jackson 1973 and Kedeba 1978) reported that in Nigeria pines respond to added nitrogen as ammonium sulphate –(NH4)2 So4,but not as urea (CO(NH2)2 more over, urea caused 50% mortality at seedlings. Soluble phosphate is best for might PH soils, Mineral phosphate for more acid ones. Some rock phosphates, e.g. petite sources at p such as from kola, USSR, have proved poor, but usually the source at p has not been especially important, e. g.(Matos and Michel 1984).

Finally fertilizing should not be on isolated operation but considered as part at tending operations to aid rapid establishment. There is ample evidence that the presence of weeds usually reduces the size of response to fertilizer application. For example, Schultz (1976) reports that *Eucalyptus cloezhanta* in South Africa failed to respond to Npk fertilization because of completion from grass (set aria), also, in general, application of herbicide and fertilizer gives a superior response compared with application of fertilizer alone even if weeds wire not obviously completing with the tress.

But there are two other reasons for combining used control with fertilizing. First, fertilizer will stimulate used growth as well as the tree. If this is not checked the benefit at fertilizing can be lost if the tree is slumped by vigorously growing weds and suffers in competition, e.g. for moisture, secondly. The stimulus to growth from combining fertilizing and weed suppression hasten canopy closure and usually reduces the numberless weeding needed,

thus the cost at initial weed control and fertilizer may be recouped by femur wee dings being needed overall.

**Stimulating growth:-**

All fertilizing should aid tree growth, but on many sites where growth is moderate addition at fertilizer can give a worthwhile improvement. In brazil Eucalyptus usually grow quit well without fertilizer, but addition of NPK fertilizer containing a high level of nitrogen often boosts productivity by 50 %( Mello 1976). In South Africa applied of NPK (3:2:1) is a standard recommendation in cultivating. Eucalyptus grandis and, except where compute soil cultivation is possible, application of 150gram at NPK per tree generally double 1st year height growth (Schonau 1985) . In Columbia *Pinus caribea* has been found to respond to several fertilizers, notably Potaciam, Phosphate/ baron and magnesium (Bolstadat al 1988) and in Cuba Phosphate application increased yield of *pinus caribea* by 56- 69m3/ha 13 years after planting (Herrero et al 1988).

**Trend in use at fertilizer:**

In many countries fertilizer at planting is now standard practice. In queens land, Australia 1434o ha, 1197o ha and 715 ha or more of plantation were fertilized in the 3 years 1986|87to 1988\89. For South Africa fertilizer application is an integral part of silviculture. Similarly for Brazil, in so bah, Malaysia, phosphate at planting is standard practice for *Gmelina arborea* and *Acacia mangium* plantation. In India in Agro forestry\Tangy plantation fertilizers are applied to increase the crop yield as well as tree growth but in Nepal Sagarnath taungya plantation only some farmers applied fertilizers for 2nd crops, but not in forest plantation alone. Overall m tropical countries fertilizer use in rising, though proportionally, comparatively little is used in Africa despite need (peter 1989)

Economics and the importance of growth response:

Fertilizing cost money, but it is hoped that the improvement in the site will be rapid by greater yields of wood. To decide whether fertilizing is economically worthwhile the most important factor, in addition to the cost, interest rates, rotation length etc, is the size at the response interims at higher yield or shorter rotation.

**3.10 Concept of irrigation in plantations.**

Except for seed orchards, nursery and other specific sites of very intensive tree culture, there is little use of irrigation in forestry. Irrigation water is usually more valuable for agriculture use. There are a few places in the world where hybrid populous and other species of alluvial flood

planning are grown with supplemental irrigation water. The most common ways of increasing the water supply of forest traces are the various methods of reshaping the ground surface to concentrate surface runoff water on the roots of planted tree that were mentioned in connection with mechanical site preparation. As watering a plantation is both difficult and expensive, it is usually not done but following are some exceptions to the general rule.

i. Dry tracts where irrigation is easily available
ii. Roadside avenue planting and
iii. Casuarinas plantation in coastal sands.

In the dry and arid areas, irrigation becomes necessary for the establishment at seedlings and the success of the plantation. In the road side avenues, the plants are watered during the first and second year to accelerate their growth so that they are beyond the reach of cattle as early as possible. In the coasts sands, casuarinas plantations are irrigation during the first year, and sometimes during the second year, to help the seedlings to send their roots through the non-retentive sand to the water table as possible to escape drought mortally.

# UNIT 4 SILVICULTURAL TREATMENTS / TENDING OPERATION

**Silvicultural treatments:**

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

**Definition: -**

Silvicultural treatment may be defined as an operation/treatment carried out for the benefit of a forest crop, at any stage of its life between the seedling and the mature stages. The treatments cover both on the crops and on the competing vegetation e.g. weeding, cleaning, thinning and even improvement felling and also pruning, climber cutting and girdling of unwanted growth, but does not include regeneration felling and ground operation like, soil working, drainage, irrigation and control burning. (L.S. Khanna 1993)

**Thinning:** Thinning may be defined as a felling made in an immature stand for the purpose of improving the growth and form of the tree that remain without permanently breaking the canopy.

**4.1 Basis of thinning**: - thinning should be done on the basis of following things;

- Age of crop, Height of crop
- Density of crop (stand Density index) Or N/D relationship - Basal area
- $N/H^2$ relationship. - Bole area
- Tree area ratio. - Spacing and top height Relationship
- Objective of management

| Age of crop: - | | Height of crop |
|---|---|---|
| Seeding – | no need | 7 to 9 m……tope height |
| Sapling – | no need | |
| Pole- | | |
| Middle aged | | |
| Pre mature aged | | |
| Mature – aged. | | |

**Stand Density index: -** stand density index may be defined as the number of tree corresponding to a given standard diameter. By determining equation for a fully stocked stand, a standard equation can be found out. This method was first proposed by Rein eke (1933) who chose a standard diameter 25cm and corresponding standard number of tree as 1000/Acre or 2200 tree/ha.

**$N/H^2$ relationship**: -It has been found by several foresters that for a given site quality, the optimum number of tree per unit area is universally proportional to the square of the height of the stand i.e. and $I/H^2$.

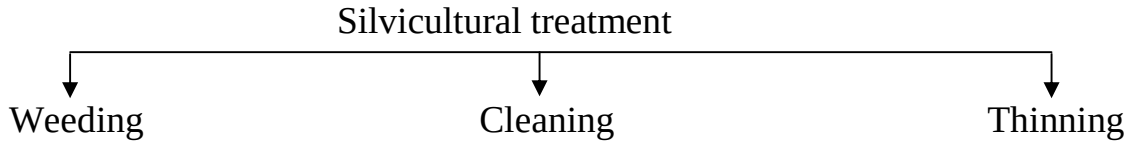
**Tree area ratio**: - is the ratio between the ground areas occupied by the tree in the stand to its total area, as an index of stand density.

**Basal area: -** As the basal area lift after each thinning is a constant percentage of the basal area of a fully stocked stand of a given average diameter, it has also been proposed as a measure of stand density.

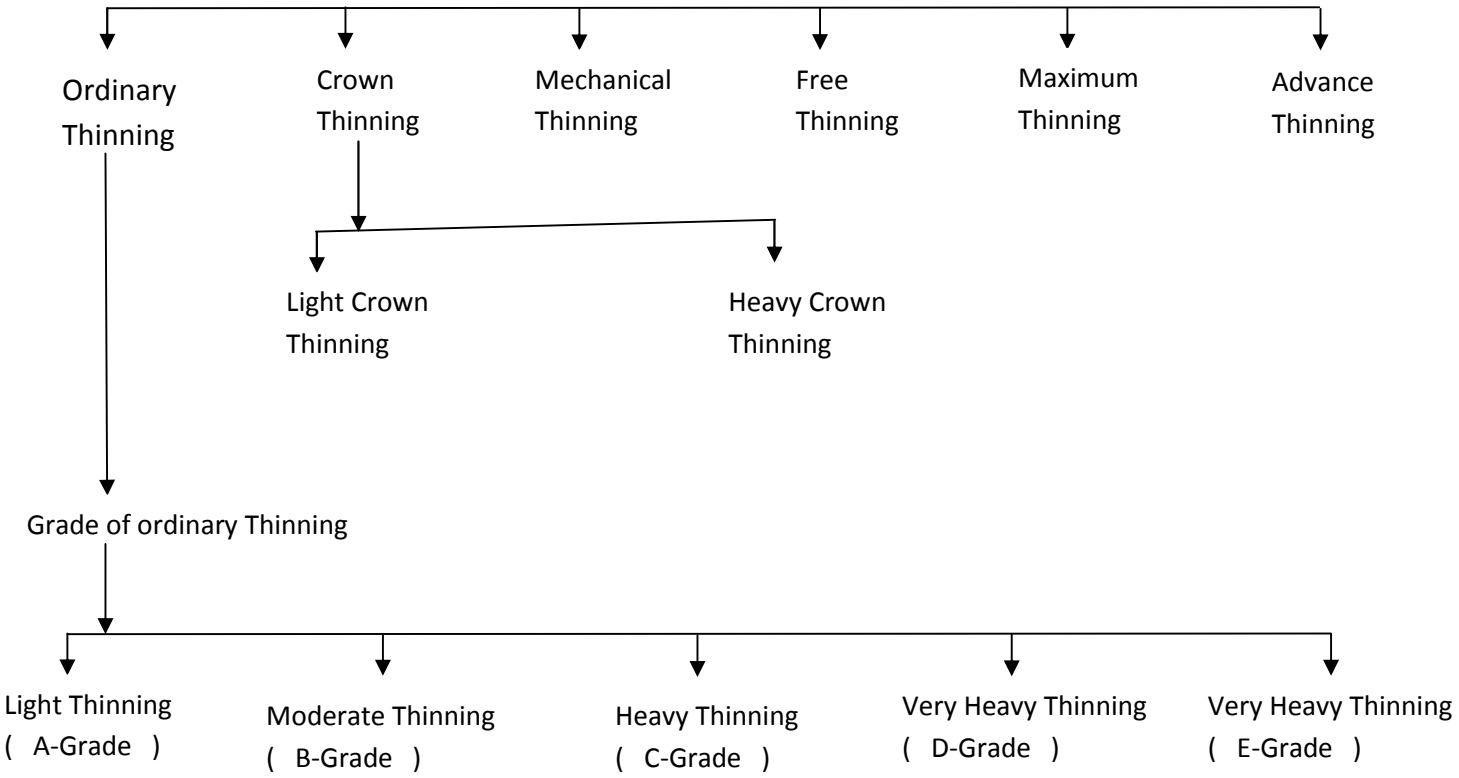
**Bole area**: - As increase in volume of trees is proportional to cambial or bole area (Laxen 1943) proposal that bole area is better measure of stand density.

**Spacing and top height relationship: -** "Humel" advocated the use of spacing and to top height relationship to be used as a measure of stand density. A lot of attempts have been made to apply this method but did not get significant satisfactory result.

## Types of thinning:-



**I. Thinning in Regular crop**:-




- ✓ Thinning in mixed plantation
- ✓ Thinning in coppice crop
- ✓ Thinning to a formula
- ✓ Thinning in irregular crop

**II. Thinning in irregular crop:-**

- ✓ Selection thinning
- ✓ Improvement felling
- ✓ Girdling
- ✓ Pruning
- ✓ Climber control
- ✓ Cultural operation

**Effect of thinning**: - following results may be obtained after the different types of thinning:-

- ❖ Physiological effect &
- ❖ Mensurational effect

1. The regulation of hygiene of the crop by removing dead, dying, diseased and infected plants.
2. Got assure best physical condition of growth, increase the rate of growth, shortening the rotation.
3. It ensures uniform distribution of trees all over the area.
4. It helps to choose the right type of tree of right spp. as future crop.
5. It minimizes the climber damage and help to reduce the fire hazard.
6. It helps to get the timber of desired quality and strength.
7. It keeps sufficient stock in the crop for the development of better bole form and maintains the soil fertility.
8. It increases the net yield of timber and money from the stand.
9. It helps to obtain the earlier returns without interest from capital in a stand.

**Methods of thinning**: - following methods have been adopted - (David M. Smith 1989)

**i.** **Low thinning**: - thinning from below or ordinary thinning or German thinning.

**ii.** **Crown thinning**: - thinning from above/top.

**iii.** **Selection thinning or thinning of dominants**: - In selection thinning, dominant trees are removed in order to stimulate the growth of the trees of the lower crown classes.

**iv.** **Geometric thinning**: - the trees to be cut are chosen on the basis of some predetermined spacing or other geometric pattern.

**v.** **Free thinning**:- cutting designed to release crop trees without regard for their position in the crown canopy are Free thinning, In the sense of being unrestricted by adherence to any one of the other methods of thinning

**According to L.S. Khanna:** Methods of thinning are;

i. Stand Density Index (SDI) or N/D relationship: - No. of trees /ha. Of certain diameter.
e.g. 2200 tree / ha. of 25 cm. diameter.

ii. $N/H^2$ relationship: - the number of tree per unit area is inversely proportional to the square of the stand i.e. No. $CI/H^2$

iii. Tree area ratio: - which is the ratio between the ground area occupied by the trees in the stand to its total area, as an index of stand density.

iv. Basal area method: - As the basal area left after each thinning as a constant percentage of the basal area of a fully stocked stands of given average diameter, it has also been proposed as a measure of stand density.

v. Bole area: - As increase in the volume of trees is proportional to cambial or bole area Laxen 1943 proposed that bole area is a better measure of stand density.

vi. Spacing and top height relationship: - Humel advocated the use of spacing and top height relationship to be used as a measure of stand density. Many attempts have been done but did not found satisfactory.

**<u>According to J. EVANS</u>:** Methods of thinning are;

i. Systematic thinning
ii. Selective thinning
iii. Other methods of thinning
   - Queensland selection thinning
   - East Africa
   - Papua New Guinea etc.

**<u>Regulation of thinning</u>**: - As we know the importance of thinning as a silvicultural treatment. The time of first thinning creates problem because the materials from the first thinning are usually unsalable, and the materials lying on the forest floor which increase the fire hazard. Due to that always a tendency to avoid/postponed first thinning materials are saleable. But the thinning impact on the tree growth, production of quality of timber, sustain the composition of stand, maintain the hygienic condition, so tendency postponing the first thinning is harmful silviculturally as well as economically in the final analysis .

The first thinning should be done whenever it is silviculturally necessary, whether the thinned materials should be saleable or not and the thinned materials should be removed or disposed of even at cost so not to constitute a danger to the crop.

The first thinning is usually prescribed by at a certain age keeping the average growth in view but sometimes due to better or poor site and environmental factors, the growth is faster or slower, therefore there is often, a provision for inspection of plantation and advancing or postponing thinning in areas where growth may be above or below to normal respectively.

The first thinning is also sometimes, timed by crop height, crop age, density of planting, objective of plantation and management, so it may varies species to species. For example in case of teak in which first thinning is carried out when the crop height is 7 to 9 m. which is reached in $3^{rd}$, $4^{th}$ and $5^{th}$ year in site quality II, III and IV respectively, similarly second thinning is carried out when the height of crop is from 10.7 m to 13.7 m. (34' to 45'ft) which is reached in $6^{th}$, $8^{th}$ &$10^{th}$ year in site quality II, III & IV, respectively.

Regarding the planting space/density, when dense, it should be thinned when the competition for light & nutrient are seen, first thinning should be done to reduce the competition.

The thinning of different species in different stands should be regularly according to need up to pre mature age.

**4.2. Pruning & lopping (Types and effects)**

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".

**Types of pruning:** - pruning can be classified on the basis of the kind of branches or the Agency of removal. Based on the kind of branches removed, pruning may be classified in to;

*Based on the kinds of branches:-*

i. Dry pruning: i.e. pruning of dead branches.
ii. Green pruning: i.e. pruning of living branches.

*According to the Agency of pruning:-*

i. Natural pruning: - natural pruning of natural death and fall of branches of standing trees due to deficiency of light, decay, snow and ice. It is also known as self pruning, carried out by the agency of nature.
ii. Artificial pruning: - pruning done by forester without waiting for nature.

Bud pruning: - is defined as the rubbing off the lateral buds to prevent the development of branches as a measure to obtain knot free timber. It is done in Salix alba, Populous, Mulberry in India. It is not widely practiced.

**Effects of pruning:**

- Produce knot and defective free quality timber.
- In some extent increase the height increment of bole.
- Produce clean bole.
- Creates space between stems in man-made plantation.
- Reduce cost of formation and rotation.
- The height up to which pruning is done should be as low as possible i.e. 40% from the bottom of total height. If the pruning is done high the tree may leaning which effects on quality of timber or may broken by wind.

**Looping:** The removal of branches from the top; it may be removal of whole branches. It is usually done for fodder and fuel wood production but tree species should withstand of looping. It effect on bole - is not used for timber production.

**4.3 Release operation (weeding, cleaning, and liberation cutting of herbicides):**

**Weeding**: - The removal or cut back of all weeds. It is done in seedling stage in nursery or in a plantation or in a forest crops. It is done to reduce the root competition and improve the light condition for enhancement of growth of plants.

Weeding should be done before weeds have started suppressing the seedlings and seedling have stopped growing, after the growth period is over.

Three weeding in first year, two in second year and one in third year but in case of fast growing spp. only one or may be two years only.

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

Objectives:-

i. To improve light condition.
ii. To reduce root competition and transpirational water loss.

Method of cleaning:

i. Cutting back of shrubs and herbaceous growth.
ii. Cutting back of the individuals of inferior species.
iii. Cutting back of the malformed or diseased individuals of the desired species.
iv. Singling of coppice shoots of the favored species.
v. Climber cutting

**Libration cutting**: - libration cuttings are those made to free a young stand, not past the sapling stage from the competition of older over lopping individuals. They are made during the same period in the life of the main crop as cleanings, differing only with respect to the age of the trees removed.

- Removal of those trees which was left in previous harvested or tress left for various reasons.
- Removal cutting of the seed tree and shelter wood methods.
- Removal of over storey trees after the establishment of new crop.
- Removal of less valuable/undesirable spp.
- Give change for additional growth of remaining seed tree.
- It should be made as early in the life as possible.

- It should be done for more benefit and least damage.
- Undesirable trees can be eliminated by cutting, girdling or chemical method.
- Girdling is less effective than herbicidal treatment in preventing sprouting.
- Girdling is done which does not sprout.
- Girdling effective in 10-25 cm. diameters while chemical treatment is done below 10 cm. of dbh.
- Cutting is quicker than girdling.
- Herbicidal treatment is superior than to either.
- It is widely employed in releasing conifers from hard wood, especially in freeing pines from oaks.

**Use of chemicals**:-

- The chemicals used for killing weeds in agriculture called herbicides.
- The term Silvicides - forest killer- used word poison- caused all kinds of problems with public and labour.
- Most compound used herbicides killed vital tissues.

**Auxin herbicides**:-

- Chlorophenoxy, simply 2, 4-D acid was 2, 4-D (Dichlorophenoxy acetic acid - developed during 2nd world war.
- 5 - T Triethylamine – water soluble.
- Butoxy ethanol ester.
- Prophy lene glycol butyle either ester - most commonly used.
- Substituted ureas are one of the newer groups. They are typified by fenuron which is-

3 phenyle -1
1 dimethy urea } these are water soluble used in soil and observed from root- It interrupted in photo synthesis process.

Most grass killer is Dalapone or - 2, 2- Dichloropropoinic acid mixed with other chemical- grass and bushes.

Sodium arsenite - used on cut surface Ammate & Ammonum sulphate - (NH4 SO3 NH2)

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

Improvement cutting are made in stands which Past the sapling stage for the purpose of improving composition and quality by removing trees of undesirable species, from, condition from the man canopy. The most fundamental characteristics of improvement cutting aside from

the fact that they are delayed until the main crop is past the sapling stage, is the elimination of poor trees in favour of good tree. The stems removed include;

1. Inferior species
2. Crocked, leaning, extremely limbs or otherwise badly formed trees.
3. Over mature individuals.
4. Trees seriously injured by biotic or atmospheric agencies.

**Objectives**: - To find and encourage the good trees rather than merely to look for undesirable trees to eliminate. In tree improvement cuttings the basic objective is to release pre-existing trees rather than to make away for reproduction.

Operation to be done in improvement cuttings as follows;

1. Felling of dead, dying (more than 75% dead) and diseased trees.
2. Felling of unsalable unsound, over mature trees which are not likely to survive up to the next felling, provided they are not required for frost protection or soil cover.
3. Felling of unsound and badly shaped mature or immature tree provided their removal will benefit better tree of the same or more valuable species.
4. Thinning of congested group of poles and trees likely to benefit from the operation.
5. Cutting back of badly shaped and damaged sapling and advance growth expected to give better coppice shoots. This should be done only when complete overhead light can be provided; otherwise coppice would not come up vigorously.
6. Removals of undesirable undergrowth of trees of inferior species which are prevent or likely to prevent the development of regeneration of desired valuable species.
7. Climber cuttings.

**4.5 salvage & sanitation cutting:**

- Removing trees that have been - imminent danger of being killed or damage by injurious agencies.
- Competition between trees.
- Highly valuable tree

**Sanitation cutting: -** Elimination of tree attached or appears in imminent danger of attack by dangerous insects and fungi in order to prevent these pests from spreading to other trees.

- Such cuttings are not confined to the removal of merchantable tree.

**Objective of salvage cutting**:-

- To utilize the injured trees with the idea of minimizing the financial loss.
- To reduce the damage against fungi, insects, fire, wind and other agencies.
- Reduce the resulting losses.
- To prevent the financial losses.

Regeneration after salvage cutting is often difficult, if the residual stand is too young or poorly distributed to provide reliable source of seed.

- Salvage cutting is frequently premature from the stand point of view obtaining natural reproduction because the damaged tree may be or large crops of seed before they die.
- Foresters face serious loss through deterioration of damaged timber, heavy expense of planting.
- It can be solved by the temporary reservation of less damaged tree as source of seed.
- Salvage cutting should be completed as soon as possible after mortality or injury has occurred.
- Harvesting of damaged tree is often more difficult and expensive.
- Salvage cutting will be necessary from time to time in any forest.
- If the main source of damage is wind, ice or lather climatic agency, and the mechanical structural stand are the important criteria.
- When biotic agencies or physiological factors, the vegetative vigor of tree is criteria.

Sanitation cuttings differ from other form of salvage cutting only to the extent that they are combined with or represent precautions to reduce the spread of damaging organisms to the residual stands.

- Sanitation cutting may also be undertaken to anticipate of attack to prevent establishment of damaging organisms.
- They can be done combined with salvage cutting.
- Any cutting is a sanitation cutting which eliminates trees that are present or prospective source of infection for insect, fungus that might attack other trees.
- If the pests are parasitic on living tissues, it is sufficient to kill tree.
- If the insects or fungi are capable to multiply as saprophyte is in dead material may remove, burn or spray insecticides.
- If fungi infested to root, stumps should remove.
- If organisms spread rapidly over long distance, sanitation cutting may be meaningless – simple salvage cutting is more common than sanitation cutting.

**<u>Prescribed burning & Fire management</u>:**

Weeding; 2-3 years. Two burning in a year; 1$^{st}$ burns for grass before leaf shedding and 2nd burning after leaf shedding.

**Advantages:**

- To improve the soil and under growth conditions for inducing natural regeneration.
- Clearance of the site for regeneration.
- Hazard reduction, like fire hazard.

**Disadvantages**:

- Damage to forest trees.
- Damage to regeneration.
- Damage to fauna.
- Damage to production power of forest.

**Fire management:**

Man is responsible for fires in the forests. Though control use of fire has many advantages, uncontrolled fires result in enormous damage to forests. That is why fire is said to be a good servant but a bad master.

- Constructing and manage the fire lines.
- Control fire according to need based on site and condition of regeneration.
- Construct fire tower.
- Fire fitter, water tank, fire brigade, mobile team.

**4.6 Effects of prescribed burning and fire on regeneration:**

There are advantages and disadvantages means beneficial and adverse affects of fire based on use. The following are some of advantages and disadvantages of controlled use of fire in forest areas;

1. **Improvement in soil and under growth conditions for inducing natural regeneration**: controlled use of fire results in increase in bacterial activity with the result that nitrate production is augmented. It consumes undecomposed litters and makes potash available. In area with dense evergreen undergrowth, control fire reduces the density of undergrowth and makes conditions suitable for natural regeneration to come up. In other areas too, controlled fire reduces the weed growth and provide a clean seed bed. Because of these benefits controlled use of fire has become a regular silvicultural practice and it is increasingly being used in obtaining natural regeneration of Sal, Teak and pine, particularly in moist areas.

2. **Clearance of site for artificial regeneration**:

   - Fire is used in cleaning plantation sites of weeds, grasses, shrubs and felling refuse.

- A good burn in the area not only provides clean seed bed but also reduces weeds and consequently cost of weeding to be done later. That is why plantation site in tropical and subtropical zones are burnt after clear felling.

3. **Hazard reduction:** controlled use of fire burns most of the inflammable material, other than accidental burning that results in diminishing the chances of fire starting or spreading in them. That may occur from an accidental summer fire. In all forests there is always a lot of dry branches lying on the ground. In addition there are a lot of dry shrubs and grasses. All this constituents a serious fire hazard. Therefore, before the summer, all the inflammable materials are burnt under control so that the summer fire may not be disastrous. Felling result in leaving a lot of felling refuse in the area, which may cause of sever accidental fire during summer. Therefore as soon as possible after felling refuse is burnt.

   On the other hands uncontrolled fire results in following damages to forests;

   i. Damage to trees: the damage done to tree by uncontrolled fire varies with species, age of tree and the season.

      - Thick corky barked spp. less affected.
      - Most broad leaved spp. with thin bark effected.
      - Most conifer spp. badly affected due to resinous materials.
      - Poles and sapling – most effected than mature trees.

   ii. Damage to regeneration:

   iii. Damage to soil: in burns down the organic matter, thus soil laid bare – exposure of sun, rain and wind cause erosion start, soil structure seriously affected. Nitrogen reserve of the soil is depleted. Uncontrolled fire makes soil compact effect on clays is extremely bad.

   iv. Damage to fauna: the animal life of the forest is destroyed.

      - Destruction of valuable environment.
      - Natural equilibrium is seriously affected and this has an adverse effect on forest vegetation.

**4.7 Relationship of silvicultural treatment with the bio-diversity conservation:** Please consult books.

## UNIT 5 AFFORESTATION/REFORESTATION OF DIFFERENT TYPES OF AREAS

### 5.1 Objectives and importance of afforestation and reforestation

OBJECTIVES AND IMPORTANCE OF AFFORESTATION

1. Increase the yield from forest to meet the fast increasing demand of timber for building construction, industries, defense and communications.
2. Shorten the rotation by raising fast growing species.
3. Locating forests with relation to the location of industries.
4. Meeting the demand of agricultural implements, hosing, fodder and firewood of the rural population.
5. Improvement of agro-ecosystem, control of erosion and beautification of countryside.
6. Concentration of work resulting in easier supervision, easier mechanization of operation, cheaper logging and extraction, and
7. Increasing employment potential.

OBJECTIVES AND IMPORTANCE OF REFORESTATION

1. To supplement natural regeneration
2. To give up natural regeneration in favor of artificial regeneration
3. To restock forests destroyed by fire and other biotic factors
4. To change the crop composition
5. To introduce exotic.

### 5.2 Locality factors, choice of species-and methods of plantation in following areas

**Choice of species and Afforestation:**

To get success in artificial regeneration, suitable species selection is the most important. If we could not select the suitable species plantation may be failure and then will have to bear a big loss of money and time. Therefore, at the time of selection of species following factors should be considered;

a) Climate and micro-climate
b) Soil condition
    - Lime rich soil
    - Stiff kankar clay
    - Clayey soil
    - Soils with soluble salt
c) Stage of succession
d) Objective of management
e) Consumer's requirement
f) Growth rate
g) Availability of suitable exotic
h) Ease to propagate

i) Ease to establishment
j) Cost
k) Effect on site

### 5.2.1 Denuded hill slopes

About 85% area is covered with hills in our country. They are slopy, some are covered with vegetations and some are naked eroded and degraded. In most area some vegetal cover establishes naturally, but in drier parts of the country, their afforestation becomes a matter of importance not only for productive and bio-aesthetic reasons but also for conservation of soil and water.

**Locality factors & other conditions**:

Soil is poor, shallow and stony. Excessive soil erosion has washed exposed to severe wind erosion. Excessive runoff results in low soil moisture content. As these areas are completely denuded afforestation has to be done under complete exposure to sun and drying winds. Excessive runoff results in deficiency of soil moisture and nutrients.

The incidence of grazing which is one of the most important causes of denudation is very heavy. Therefore protection of plants raised under afforestation scheme is a great problem. Besides this illicit felling, forest firing and other form of damages by local people.

Generally such, this type of lands are the property of the local people they neither afforest the area nor allowed it to be done the forest Department. Now if such type of lands is under government, they have been given to the community (FUG) for afforestation, protection, management and utilization of products under community forestry program.

**Closure**: Before starting afforestation work it is necessary to close the area by fencing or by the co-operation of local people against felling, grazing & firing for 2-3 years. This helps the nature to cover the area with some vegetation, including grasses and creates favourable condition for afforestation.

**Soil Preparation**: Preparation prior to raising trees may be carried out by the under mentioned two methods.

**a) Contour trenches:**

Contour trenches are usually made on slopes up to 20% as the operation becomes costly on steeper slope. They are usually made with the help of any levelling instruments. In forest Abneys level and or locally made wooden contour frame, figures of two of which are given below.

1) A contouring frame in the form of letter "A" of English alphabet is made of 5 to 6 cm wide, l to 2 cm thick sawn timber pieces. Two such pieces are joined to make A of height 1.5 m with legs about 2m apart. To keep the legs in position, they are struted with a horizontal piece on which its middle point is marked. A plumb bob is suspended from a nail fixed in the apex. When the thread of the plumb bob passes through the middle point mark of the horizontal piece, the two points on which the contouring frame stands, are on the same contour.

2) Another contouring frame is made of 6 cm wide, and 1.2 cm thick sawn timber pieces. Its legs are 3.6 m apart while top piece is 3 m long and centre height is 1 m as shown in figure. In order to use spirit it, a sprit level is required. When the air bubble of the spirit level placed on the middle of the top piece, is in the centre, the points which the legs of the frame touch, are on the same contour.

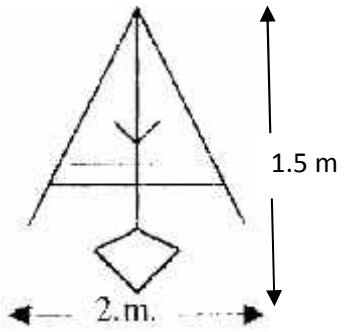



Fig: contouring frame with a plumb-bob

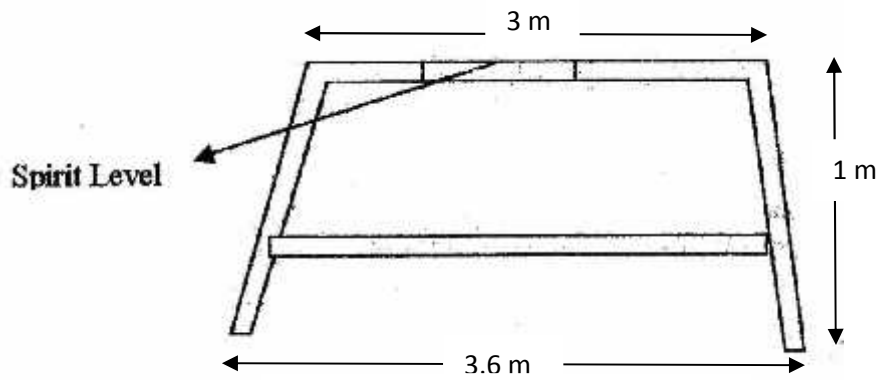



Fig: contouring frame with sprit level

In order to mark out the contours on a slope, the work is started from one side of the slope. Having selected the starting point, a peg is fixed there and one leg of the frame is placed there. Then the other leg of the frame is rotated slowly till the plumb-bob of the first contouring frame or air bubble of the spirit level of the second is in the centre. This is the point of the second leg. A peg is driven at this point. The work proceeds in this way. The trench is dug after marking a straight line between pegs. The trenches may be continuous or interrupted. Of the two, the interrupted trenches are considered better. The trenches are generally 3 m long and 30 cm deep but trench should be level. The distance between the successive lines of contour trench may be from 2 m to 4.5 m depending upon the angle of slope. The cross section of the trench depends upon the average daily rainfall.

The trenches are either filled in ridge-ditch pattern with a continuous ridge of earth or the trenches are left empty for catching water and soil and a ridge is made about 15 cm away from trench on the lower hills side.

**b) Patches or Pits**:

Usually adopted where slope is rocky and contour trenches can not be made, patches or pits are selected for sowing or planting without bothering for regular spacing.

**Choice of Species**:

The selection of spp. depends on different factors but should be selected indigenous spp. as possible. This fast growing, non-palatable spp. which can survive under the adverse conditions. It is advisable to start with either pioneer species or species that occur in the earlier stage of succession. For example; a few species that are used in afforestation of the denuded hill slopes are given below:

Temperate: Pinus *wallichiana, Cederus deodara, Juglans regia,Quercus spp, Rhoddendron spp, Alnus nepalensis.*

Moist sub-tropical: *Pinus roxburghii, Pinus patula, Castenopsis spp,. Alnu spp.etc.*

Dry sub-tropical: *Acacia modesta, Accacia auriculiformis, Acacia catechu, Prosopis julflora, Acacia molicima, Robinia pseudocacia.etc..*

In Chure hills: Schima *wallichii, A. Catechu, Cassia siamea, A auriculiformis, Bamboos and grasses. eg. Eulelioapsis binata etc.*

**Method of Raising Plants**:

For the spp. mentioned above, planting of nursery grown seedlings are the best but for some spp. direct sowing may be done.

**Tending**:

Weeding may have to carry out once or twice in a year. Depending upon the local condition it can be continued for some years. However, weeding should be done continuously so that the plants do not suffer from insolition.

**Treatment of gullies**:

To check erosion, stone or brush wood check dams are provided or masonry check dams may be constructed where ever necessary. When the dams get silted up the area is planted with *Agave, Ipomea, Arundo, Donax and Vitex negund etc.*

### 5.2.2 Abandoned cultivated lands

In hilly areas, there is cultivation of agricultural crops for many years without balancing the soil fertility, gradually fertility of soil become poor and deteriorate the soil. The lack of tree vegetation leads unwanted weeds come out and effect the insulation and frost the agriculture is not to be economic and farmers in forced to abandoned the land.

Sometimes straighten the boundary of the reserved forest; some cultivated lands may have been included in the reserve in exchange for forestland. Illegal cultivation or encroachments in the national forest lands are given up.

**Factors of Locality**:

Soil may usually be poorly fertile because of repeated raising of agriculture crops without manuring, and of the top soil being washed away. Drainage, aeration and moisture content of soil is also poor. The conditions become further worse, if the abandoned field was previously used for storing water and puddle for rice crops. Because of the fact that the land remained under cultivation for a long time, soil organisms beneficial for tree growth may have disappeared. Weeds may be heavy if the period of time between cultivation and tree raising is long.

**Soil Preparation**:

As far as possible, afforestation should be started immediately on abandonment of cultivation. The greater the time lags, the greater will be the difficulties. After the area goes out of cultivation, afforestation may be easily done by taungya method. If this is not possible, soil may be dug in strips whose width would depend upon the height of weed growth and the rate of growth of the desired species. If the tree is large and plain, tractor ploughing may be done. Conditions for improved drainage should be created.

**Choice of Species**:

The choice of species depends on the ease in raising, rate of growth and frost hardiness. As the soil is already deteriorated, species found in the earlier stages of natural succession in such area should be selected. Mixed plantation should be raised in preference to pure plantation.

**Suitable Species**: in Sal area Sal; in lighter soil Khair, Siris, *Terminalia, Eucalyptus, Ipil, Cassia siamia* etc. in hills Pines are suitable.

**Method of raisins Plantation**: Sowing and Planting both are suitable. Sowing are done in strips and polybag seedlings in pits or stump planting may be used.

**Tending**: Weeding and cleanings have to be done for several years if the area is heavily infested with weeds.

### 5.2.3 Grasslands

In Nepal's forests grass lands are found both inside and outside the forest areas. In outer Terai, Bhabar and in inner Terai grasslands have been formed in the Sal forest or Sal tracts. In middle hills in southern aspect where there are lack of tall trees and in temperate and Alpine forest there are the grass lands formed due to felling of trees, burning and grazing, which are responsible for their continued existence as a biotic climax. For example Parsa wildlife reserve, Suklaphata, Chitwan, Rasuwa and high lands of Midwestern and Far-western development regions etc. In western Himalayas, Southern aspects are generally blank and covered only with grasses and shrubs.

**Locality Factors**:

In this type of lands trees are in less number; sometime no taller trees are found. Thus, more chances of damage by insolation of sun, frost. Soil aeration and drainage arc poor and biological condition of the soil unsuitable. Some grasses e.g. *Imperata* form dense mass of roots and there by retard aeration prevent infiltration of rain water of light showers, and by arresting silt, clog the pores of the surface soil resulting in superficial water logging. Some other grasses e.g. Sacharum, Panicum etc.develop extensive ramyfying root system which is difficult to be eradicated even after through and intensive soil working,

Rapid growth of grasses makes weeding essential, costly and the growth of the desired species is seriously affected. Grasses greatly increase danger of fire and frost. They also harbour pigs and other wild animals that destroy regeneration.

**Soil Preparation**:

Special Preparations are to be done before trees are raised mainly because of the heavy grass growth. Soil preparation is done in strips. They should be wide enough to prevent them. If possible the entire area should be subjected to deep ploughing. In hills, the grasslands can be afforested by taungya method but usually patch sowing or planting is done.

**Choice of Species**:

In order to keep down the total cost of raising plantation, fast growing, frost and fire hardy species should be chosen following species are, suitable for different localities.

In Terai and Innerterai: *Dalbergia sissoo, Acacia catechu, Bombox ceiba, Leucaena leucocephala, Ailenthus excelsa, Broussonetia papyrifera, Eucalyptus hybrida, Terminalia myriocarpa.*

In hills: Chir pine, Blue pine, *Pinus patula, Alnus spp., Schima wallichi, Castenopsis* etc.

In high hills: Deodar, Fir, Spruce, *Cupressus, Populus ciliata, Eucalyptus globulus* etc.

**Methods of Propagation**:

For most of the spp. mentioned above planting nursery grown seedlings may be the best but some spp. can be sown directly in well prepared strips of soil. In Temperate zone most of the spp. are planted naked root.

**Tending:**

Weeding is necessary for two or three years and in very grassy area as in Terai agricultural crops are raised in between the rows of plantation to keep down grasses; and if this is not possible, the grass has to be harrowed down before weeding.

**Protection**: Protection against fire is essential.

### 5.2.4 Ravine lands

The ravines of Seti different from Koshi and many Chure rivers have not only rendered extensive areas barren and become strong holds of dacoits but are also posing a serious danger to the cultivated lands above by their continuous extension backwards.

**Locality factors and other conditions**:

Once the ravines are formed, they continue to extend backward or to cut back wards into their headwaters and destroy even the vegetative cover on lands above them. Soil varies from sandy to stiff clayey with enough lime which develops into kankar pan. This obstructs the rainwater from in filtering deeper into the soil. The average rainfall varies from 200 mm to more than 1000 mm. Superficial kankar pan prevents storage of sufficient moisture in the top soil soluble salts are concentrated just below the surface giving rise to chronic saline alkaline soil.

**Soil Preparation**:

**1) Soil preparation in the catchment**: Contour bunds are constructed at suitable intervals in the catchment area depending upon the slope of the land. If catchment area is cultivated contour are constructed. If the excess water is drained by these bunds, there should be made the diversion channel of grassed waterways. Staggered trenches are dug at a spacing of 3.5 m x 4.5 m on the same contour line or lines which are 4.5 m apart.

**2) Soil preparation on the slope of head and the sides of ravines**: If the slope of head and sides of the ravine is more than 30°, no any operation is tried due to fund problem, and is not in practice. Where the slope is less than 30° a continuous trench 60 cm wide and 4.5 cm deep is made about 2.5 m from the base of the steep slope of the head and the side of ravine. The interval between two trenches is 4.5 m but after, 4 to 5 rows of trench, one long continuous trench should be constructed.

The dug up soil of these trenches after weathering is either filled back in ridge ditch manner or is made into a continuous ridge along the lower side of the trench which is left empty.

**3) Soil preparation in the valleys**: Continuous trenches are made in the valley areas. The first trench is made 1.5 m away from the base of the head of the ravine and there after they made at an interval of 4.5 m. After 2 to 3 trench means 4rt trench should have 1 m interval to pass the surface water or a safe passage for water is provided at regular interval.

**Choice of Species**:

The surviving indigenous species give the best indication of what should be grown. The fallowing species may be adopted under different soil conditions.

**i) Sandy Soil**: *Acacia catechu, Melia azadirachta, Prosopis julflora, Dalbergia sissoo, Pongamia pinnata, Cassia siamia,Albizziz spp.*

**ii) In clayey soils**: *Acacia arabica, Acacia leucophloea, Terminalia arjuna, Prosopis spicigera, Syzygium, Ailanthus, Albizzia, Holoptelia etc.*

In between the trenches forming a ring on the three sides of the ravine, some grasses e.g. *Eulaliopsis binata, Cynodon dactylon, panicum repens* etc. are raised. In good soil some legumes can be raised, like *Dollichos, Desmodium* etc.

**Mode of raising trees**:

Most of the spp. are sown in one or two lines on the ridge but some spp. are best success by planting of nursery grown seedlings. Grasses are shown directly or by planting slips root shoot cutting and presprouted plants can be planted.

**Tending**: Weeding and cleaning are done when necessary. The area is kept closed to grazing.

### 5.2.5 Dry area with or without irrigation

**1. Dry area with irrigation**:

Dry area with irrigation are available for private, leasehold and community forestry plantation in only a few district because of the fact that irrigation is not available fully even for agriculture fields. However, such areas are available for plantation work in part of Jhapa, Morang, Sunsari, Chitwan, Nawalparasi and some western part of Nepal. Afforestation of dry areas with irrigation is done on a small scale in Hariyana, Punjab and in Tamilnadu and U.P. in some extent in India.

**Factors of Locality**:

Generally the soil conditions vary from sandy to clayey with high alkalinity. A kanker pan may also occur.

Rainfall varies from locality to locality. Maximum temperature is in the region of 45° C, hot, dusty, winds blow during the summers. The temperature falls down considerably during the winter months when the condition of frost may occur.

In the government sector the area is mostly non-desirable thorn scrub forest, or the area cultivation, the existing species are heavily lopped and browsed. There, is a heavy pressure of human and animal population. Locally termites are very destructive.I

**Soil Preparation**:

The area to be planted up will have to be leveled and stumps removed so as to bring about effective irrigation. In some places ploughing is done by oxen rarely used tractors in our country. The whole area is divided in to large irrigation blocks and blocks are sub-divided into 100 or 200 ha of compartment, and compartment is also sub-divided into 10 ha plots. They should be made

on the basis of level of land. The trenches are formed about 30 x 30 cm. 27 m, long at a spacing of 3 to 5 m.

Irrigation is usually done by flooding in night. It start from the bottom of the plot upward and only 10 trenches are irrigated at a time, but care is taken to ensure that there is no over flooding.

**Choice of Species**:

The species to be adopted varies from locality to locality, depending upon local climatic conditions. The existing vegetation also gives a fair idea about the species to be raised.

**1) Poor kanker soil**: *Tamarix spp, Acacia catechu, D. sissoo, A. nilotica, Cassia siamia, Butea spp. etc.*

**ii) Soil free of salts**: *Prosopis Juliflora, Acacia nilotica, Prosopis cineraria, and Cassia spp. Eucalyptus spp.*

**iii) Mixed Plantation**: *Acacia catechu, Acacia nilotica, Bombax ceiba, Morus alba, Syzygium cumini, Eucalyptus, Populus, Dalbergia Sissoo, Acacia mangium, A. auriculiformis etc.*

**Methods of raisins trees**: Trees may be raised in the following manner

**Sowing**: Direct sowing in the field may be done for *Syzygium, Acacia, Prosopis* etc. Patch sowing, broadcast or dibbling sowing may be carried out.

**Seedling planting**: Nursery grown container seedlings are transplanted in the field during the rainy season e.g. *Eucalyptus spp., A. auriculiformis, Terminalia spp.*

**Stump Planting**: Stumps from the nursery beds are transplanted in the field, during the monsoon or winter rains. Main spp. *Dalbergia sissoo, Bombax ceiba, Tectona grandis, Moru alba and other Ficus spp.*

**Irrigation**: Frequency of irrigation depends upon the weather and soil conditions. For spring sowing or planting, more irrigation is necessary during summer. Plantation is generally, irrigated for first two to three years, after which irrigation is done if water is available. Ten to fifteen irrigations are needed in the first year, about 6 to 10 irrigation in the $2^{nd}$ year and about 5 in the $3^{rd}$ year.

**Tending**: Three weeding have to be done in first year and two in $2^{nd}$ year; when pruning is also done to prevent formation of side branches. Singling of shoot is also done.

**Protection**: protection against fire is necessary. To control the grasses and weeds, weedicides Dalapon @ 5.5 kg/ha an interval of 3-4 weeks in April and May gives 80% control of perennial grasses.

**2) Dry areas without irrigation**:

A dry area may be defined or termed as that area which receives an annual rainfall of less than 900 mm. As per this definition, about ¼ th of the country's total land area can be classified as dry, extending in almost all districts except Jhapa, Morung, Sunsari, Ilam, Kaski, Makwanpur, etc.

**Locality factors**:

The Soil varies from place to place; locality to locality with the underlying rock Denudation has deteriorated it considerably. Dry areas are generally subjected to severe wind and water erosion. Annual rainfall varies from 250 mm to below 900 mm and it falls in a limited number of showers. Thus the number of rainy days varies from 15 to 60 days and temperature goes as high as 50° C, generally frosts are very serious. Pressure of human and animal population is great and this poses a great threat to afforestation work.

**Soil preparation**: Soil Preparation has to be done in such a way so as to conserve maximum moisture that is available and also to help in the establishment of a deep rooted system. If the area is sloping, interrupted contour trenches are made. The dug up soil is usually filled in a ridge ditch pattern or hipped in the form of ridge along the lower side of the trench. The soil should not heap into a ridge on a hard ground, as the roots do not penetrate into the hard ground. If the plant roots cannot reach to the permanent moisture, they die. Various methods of soil preparation are described earlier and any one method can be adopted which are suitable for the particular locality

Following Steps of Soil preparation are adopted:

i) Soil is dug as deep as possible.
ii) Contour trenches are formed in sloping areas.
iii) The dug up soil is heaped to form a ridge along the portion of the trench
iv) Care is taken so as not to heap the soil on a hard surface, also on reaching hard ground, the roots will tend to cut sideways.

**Choice of Species:**

Fast growing, drought and frost resistant species should be selected for such difficult sites. The following are some species which may be raised under different conditions:

*Acacia leucephalea, Acacia catechu, Cassia siamia, Acacia benthenwii. Acacia senegal, Albizzia lebbek, Ailantus excelsa, Casuarina equisitifolia, Cassia fislutla, Anacardium spp., Zyziphus, Eucalyptus spp., Holoptelia integrifolia, Pongamia spp., Prosopis juliiflora, Prosopis Cineraria, Anacardium, Pterocarpus santalinus, etc.*

**Tending**: weeding and cleaning is done according to need.

### 5.2.6 Canal banks

Large strips of land occur on either bank of canals which were used as the common grazing lend, as a means of communication for canal repairing and for public use. It is estimated that over a thousand kilometer length of canal exist in Nepal along whose banks, plantation could be done. We have Kankai irrigation canal from bottom hills of Chulachuli to Mahabharat, Koshi irrigation canal from Chatra to Morang in the east and in the most of Koshi river Koshi dam to Saptari, Chandra Nahar from Trijuga in Saptri, Kamala canal in Siraha and Dhanusha, Bagmati canal in Sarlahi and Rautahat etc.

A project for their plantation is to be launched. The main aims are the utilization of waste land, protection of canal banks, and shade for passengers, production of fuel, fodder, and timber and also as a windbreak and shelter belt.

**Locality Factors**:

Soil Conditions vary from area to area, usually these vary from sandy to clayey. The site may be dry, moist, waterlogged, swampy etc. climatic conditions vary from locality to locality, depending upon the climate of the area through which the canal passes.

As the canals usually run through agricultural area where there are practically no forests, biotic pressure on canal bank plantations is very severe. This is usually in the form of over cropping, overgrazing and even illicit felling.

**Preparation of Soil**:

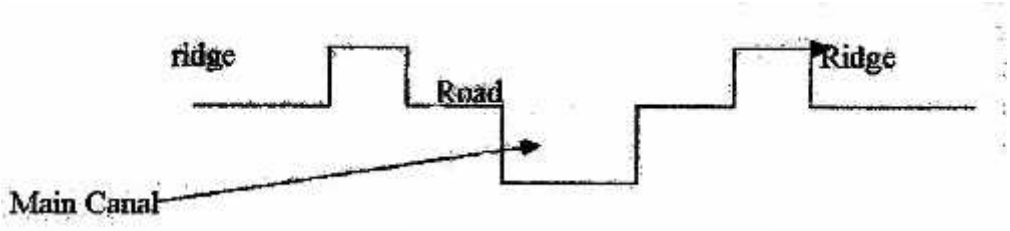



Fig: cross section of a canal

The main techniques of preparation are as follows:

i) The first row is raised along the outer edge of canal road, with plants about 6 m apart.

ii) The strip on the left bank is planted where as that on the right banks are sown. Pits for planting are of 60 x 60 cm Size.

iii) Planting is to be done on either bank. Spacing adopted in 3 x 4 m.

**Choice of Species**: The choice of app. Depends upon the soil and climatic conditions, but spp. should be hardy;

*Acacia nilotica, Dalbergia sissoo, Acacia catechu, Albizzia, Ailenthus, Melia, Grevillia robusta, Delonix regia, Jacaranda ovalifolia, Cassia javanica, Populus, Morus, Robinia pseadocacia, Parkinsonia aculeata, Swietenia macrophylla, Eucalyptus, Leucaena spp. etc.*

**Melthod of planting**:

Generally plantation is done with bole of earth, naked root planting and container plants. Some spp. are raised by direct seed sowing in pits or in strip e.g., Sissoo, Khair, Babul, Ailenthus etc.

**Tending**: Weeding should be done for two years and cleaning for one or two years or according to need.

### 5.2.7 Road side plantation

Large strips of land lies barren along the roads. In Ranas Regimes there were no motorable roads but along the footpaths there were planted which are seen in different places like path from Bhemphedi to Kathmandu. Some Eucalyptus, Mango and Ficus spp. are seen even now. In 1972 road department was started planting along the road but did not continue because the engineers were more concerned about the Engineering aspect of the road, they left work of planting trees. For example Amlesganj to Birganj road side plantation was done which are not systematic and appropriate. From 1985 the land owner road department had given this job to the forest department and has planted under community forestry Programme.

In India Emperor Ashok, was the first India king who started tree planting along the roadsides. Then Mr. Chaturvedi drew the attention of the government towards this aspect in 1938. Since then millions of trees are raised along National State highways and other roads all over India.

In Nepal both sides of roads of land is under Road Department, one two to 4-5 lines plantation is done for the following objectives;

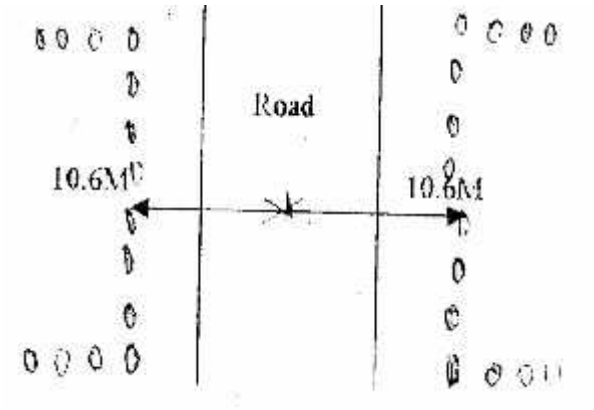
i) To provide shadow to travelers.
ii) To protect the road surface from the insolation of sun.
iii) Clear vision of road in night or day.
iv) To utilize the waste land.
v) To produce fuel, timber and fruits .
vi) To increase the aesthetic value.
vii) To moderate the temperature.
viii) To protect the Agricultural crops in some extant against the strong winds.

**Locality factors**:

Soil conditions usually vary from sandy to stiff clay. Borrow pits upset the natural drainage and may result in conditions of water logging. Climatic conditions vary from area to area through

which the roads pass. Usually very high summer temperatures are experienced, bulk of the precipitation is received during the monsoons.

Pressure of human population is very severe lopping for fodder and fuel wood is a common feature. Owners of cattle, goats, cows, sheep, buffaloes etc. let loose their animals to grave upon these areas.




**Soil Preparation**:

Pits of 60 x 60 x 45 cm are dug during the winter when the soil is easy to dig. Ridges and mounds may have to be formed in areas of water logging. Pits are dug in one to 10 rows on both sides depends on the land availability and the types of road like National highway, state highway, District highway and village road etc. Generally the row of pitting should be started 10.6 m from the centre of the road. The pits are so dug, that they are exactly opposite to each other on either side of the road.

**Choice of species**: the choice of species depends upon soil, climate and the objective of management, for example;

**For aesthetic value**: *Cassia fistula, bauhinia varigata, B. purpuria, Azadiractha indica, Saraca indica, Delonix regia, Jacaranda ovalifolia, Grevellia robusta, Camphor, Parkinsonia etc.*

**For hill roads**: Chinar, *Prunus ceratoids, Fraxinus floribunada, Lagerstromia spp., Eucalyptus spp. etc.*

**For fruits**: mango, *Anacardium oxidentale, Morus alba, Syzygium cumini, Ziziphus spp. etc.*

**For shade**: *Ficus religiosa, F. bengalensis etc.*

**For timber**: *Dalbergia sissoo, D. latifoloa, Swietenia etc.*

**For water logged areas**: *Syzygium cumini, Trewia nudiflora, Eriterina spp., Terminalia myriocarpa, Salix spp., Eucalyptus spp., Terminalia arjuna etc.*

**Method of Planting**:

Tall hardy nursery grown selected spp. seedlings are planted in pits or on ridges or on mounds in monsoon. If possible tall plants should be planted.

**Protection**: methods of protection are as follows;

i) Planting live hedge around the tree.

ii) Construction of brick circles 1.6 m high but should be net like.
iii) Empty drums of coal tar making strip cut.
iv) Bamboos tree guard.
v) By trench fencing.
vi) By barbed wire fencing etc.
vii) Iron steel tree guard.

**Tending**:

Two or three weeding for two to three years. Cleaning according to need. Pruning may also have to be done in the first few years of growth.

### 5.2.8 Farm forestry/on farm trees

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

In the western countries, a portion of the farm is assigned to raising trees, to meet the requirement of fuel timber and fodder of farm, in the same way as some portion of the farm is separated for raising cash crop, agriculture crops, vegetable etc. This is known as farm forestry because it is the practice of forestry on farmlands, generally more or less integrated with other farm operations. But in our country land holding are small so this type of practice is impossible but in practice. In country like Nepal villages are situated near the forest meet requirement of fuel, fodder and small timber from the forests but the people (village) which are far away from the forests, have to practice farm forestry, boundaries and patch planting.

Similarly in India there are less than 0.3 ha land holdings, keeping the conditions of the country in view, the farm forestry symposium held in 1958 defined farm forestry as the practice of forestry in all its aspect on farm and village land, generally more or less integrated with Other farm operations.

Farm forestry is to be practiced in our country in the following two categories of lands:

i) Individual farmers holding where trees can be raised on bunds, round farm houses, and cattle shed.
ii) Village land/ community land where groves of trees can be raised on waste lands, along streams and village roads, round village, schools, well, ponds and VDC houses.

In the first case the ownership is that of the farmer but in 2$^{nd}$ case the ownership is of village community, but altogether raising small forests for the village as a whole.

**Objectives 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 farmers from the sale of excess timber; and
5. To beautify the villages and countryside.
6. To increase the agriculture production by conservation of soil and water.
7. To ameliorate the climate condition of the villages as well as the country.

**Difficulties**:

A. Objections against trees on the bunds;
   - Shading effect
   - Root competition
   - Crops damage by birds

B. Objection against small forests on village waste lands or commons;
   - Reduction of grazing ground.
   - Animal damage to crops.

**Choice of Species**:

According to the climate, soil, and local climate species should be selected. For different localities following spp. are suggested to plant.

**For Terai regions**: *Acacia arabica, A. catechu, Bombax ceiba, Dalbergia sissoo, Dendrocalamus strictus, Emblica officinalis, Eucalyptus spp., Moru alba, Populus spp., Syzygium cumini, Ziziphus mauratiana.*

**For hills**: *Cedrela spp., Grewia, Melia azedarach, Morus spp., Populus spp., Prunus spp., Salix Spp.*

**Dry area in plains**: *Acacia arabica, A. catechu, A. tortilis, Ailanthus excelsa, Albizzia spp., Anona squamosa, Azadirachta indica, Dalbergia sissoo, Dendrocalainus strictus, Emblica officinalis, Eucalyptus spp., Madhuca latifolia, Moringa oleifera, Parkinsonia aculeate, Phoenix spp., Prosopis cineraria, Prosopis julfiora,. Tecorna undulata, Ziziphus mauratiana.*

**Methods of Planting**: Mainly nursery grown naked root, container or with bole of earth plants are planted, sowing is rarely done in practice.

**Protection**: - Mainly from animal and goat damage.

**Tending:** Weeding, cleaning & Pruning, side branch cutting, sometimes topping and thinning should be done.

### 5.2.9 Urban forestry

Urban forestry is the practice of forestry, which has been described as the management of public and privately owned lands in and adjacent to urban centre. In this type of forestry trees are raised with the object of raising ornamental and flowering trees and shrubs mainly to serve as recreation forests for the urban and rural population but not for the production of fuel, fodder & timber.

**Objectives**:

1) To raise ornamental trees.
2) To increase the aesthetic value of urban centre.
3) To beautify the urban centre.
4) To ameliorate the climatic condition and reduce the pollution.
5) To reduce the wind velocity.
6) To provide shade to the people.

**Locality factors**:
Soil and climate vary from locality to locality or place to place but generally soils may be poor due to construction of road and buildings, bridges, drainage and culverts etc.

**Choice of species**: Following criteria should be follow for selection of spp.

1) Spp. should be evergreen with handsome crown.
2) Should be flowering tree as possible flower should be with good smell.
3) Should be branchy, drought resistant and non palatable.
4) Moderate in size, but strong deep root system.

**Suitable species:** *Cinnamomum camphora, Plecten thus Orientalies, Prunus, Mangoes, Guava, Anacardium,Morus,Jamun, Swietenia, Cassia fistula, Grevillia robusta, Delonix regia, Callistemon lanceolatus, Parkinsonia, Robinia, Tecoma stans, Eritherina, Salix, Eucalyptus, Lagerstromia flusregina, Cupressus spp., Criptomeria japonica,Fficus spp., Terminalia arjuna, T. myriocarpa etc.*

**Method of planting**: Only nursery grown tall, hardy, container raised seedlings are planted.

**Protection**: against animal damage, using bamboos & iron tree guards or bricks rings etc.

**Tending**: weeding should be done continuous for 2-3 years.