**Chapter4. Forest plantation establishment and management**

**4.1. Plantation**

Plantation is a forest community or stand that is established artificially by sowing or planting. Sometimes it is referred as man-made forest. When plants are raised in nursery they spend their first weeks in sheltered, favorable conditions and are fitter to start in the planting site than seedlings originating from direct seeding. Nursery stock gives so much more reliable results in afforestation that in spite of the higher costs, planting has far exceeded sowing in establishment of plantations all over Africa.

**4.2. The origin of forests**

Depending on their origin five forest types can be identified:

1. Forest created by *afforestation of bare land* where has not been forest for at least 50 years. E.g. afforestation of grassland
2. *Reforestation of land;* which has been carried forest within the last 50 years but the previous vegetation, is replaced by an essentially different one. E.g. the replacement of natural forest by plantation.
3. *Reforestation of land;*which has carried forest within the last 50 years by the renewal of the same vegetation as before.
4. Forest established by *natural regeneration with deliberate silvicultural intervention*and manipulation. E.g. Shelterwood method, seed-tree method
5. Forests, which have *regenerated naturally without human assistance*. E.g. all natural forests

**A plantation with one species only is called monoculture. Mixed plantations consist of two or more species.**

**4.3. Why we need plantations?**

**4.3.1. Negative factors favoring plantation development**

**Past and continuing destruction of natural forests**

Natural forests have been cleared for a long period of time for agricultural expansion, for exploitation of timber, charcoal, firewood, urban and industrial expansion and this has led to a severe shrinking of the natural forest to an extremely small proportion. As a result the existing remnant forests can no longer satisfy the increasing demand for various forest products.

**Problems of access to existing forest**

Some natural forests are located in a difficult terrain, like swampy ground and steep mountainous terrain. On the other hand through continued exploitation of natural forests, the location of existing forests have receded to very remote areas that are very far from the potential users of the wood – forest industries and urban areas.

**Unsatisfactory natural regeneration and lack of management**

Considering the natural forest condition obtaining a satisfactory regeneration of merchantable species is very difficult. The required silvicultural interventions to bring about adequate regeneration and growth of desirable tree species are very complicated tasks as compared to plantation silviculture.

**4.3.2. Positive factors favoring plantation development**

**Land availability**

In most developing countries a vast area of land that is marginalized by poor agricultural practices and deforestation, is potentially suited to tree planting purposes. In many respects, forest plantations will be the best alternative land use to bring such lands to an economically productive area.

***High productivity***

Plantations have higher productivity than natural forests for the following reasons

* Plantations are established artificially offering a possibility of making species choice with respect to its adaptability to the site, degree of its social and economical value with regard to the quality of its product.
* Planting could be done with a desirable spacing and density and also can be manipulated throughout its life resulting in a desirable mix of products (pole, firewood, sawlog). This will also enable an even and near optimum use of the site’s productive capacity.
* Plantations give a homogenous, uniform, and higher amount of product from an appropriate species. (Some 10 to 20 fold of native forests)

Management, maintenance and harvesting of plantations are much easier as they are composed of few species and they are systematically spaced.

**Plantation as a tool for development**

As an integral part of the forestry sector plantation programmes contributes substantially to the economic development of a country.

* Supply raw material to forest industries
* Plantations in social forestry make great contribution to rural development – supply all required wood products for consumption and commercial purposes
* Forest plantations can be established for protective purposes on problematic sites
* To stabilize soil : by protecting from erosion, controlling run off in Catchments areas,
* Providing shelter from wind and heat and against sand and dust storms

**4.4. Main objectives of forestry in Ethiopia**

**4.4.1. Protective functions**

Forests have many beneficial environmental influences. The retention or planting of trees for the main purpose of using their environmental influences is protective forestry. The major environmental problems with severe consequences now a days in Ethiopia are:

- Desertification and drought

 - Land degradation

- Flooding

Directly or indirectly the rapid and continued deforestation activities that has been taking place for a long period of time has contributed very much to the intensification of these problems. Therefore expansion of forest cover is one of the main measures to be taken to control and reduce this major environmental problem. In general soil and water conservation can be taken to be the prominent protective role of forests in Ethiopia. Deforestation and subsequent land degradation will eventually lead to the total loss of the biological potential of the area.

*Protective plantations can be established in different forms*

* ***To rehabilitate degraded sites***: plantations of appropriate species, most resistant to extreme environmental conditions, will be planted to protect and improve the soil conditions of inhospitable sites.
* ***To protect exposed hillsides:*** trees will be planted on steep slopes, usually along the contour to slow down the run off speed and prevent the soil from being washed off. Such plantations are supplemented by construction of some soil conservation structures like terraces.
* In ***agro forestry***: protective tree planting activities can also be integrated with agricultural activities. In this case trees will serve productive and protective purpose - supply fuel wood to the rural people thereby reducing the consumption of dung and crop residue. Also help prevent degradation of agricultural land by soil erosion, reduce overgrazing by providing fodder to cattle.
* As ***Shelterbelts/Windbreaks***: are long stretches of tree planted to prevent soil and agricultural crops from harmful winds.

**4.4.2.Production forestry**

All tree planting and forest management activities done with the main purpose of producing forest products for consumptive or commercial purpose constitute production forestry. The products from forest can be collectively classified as wood products and non-wood products. Forests can be managed to produce one or combination of these various products.

**A. Wood Products**

* **Industrial wood**

The major forest products for industrial use in Ethiopia are fuelwood, sawlogs and plywood or logs for veneer. They are usually panted in large scale by forest enterprises, forest projects or by the end-users themselves-factories and industries

* **Construction wood**

Construction wood includes poles and fencing posts. These are produced by large projects, communities or individual farmers.

* **Fuel wood for domestic consumption**

These are commonly established by private individuals and communities to supply their fuel wood demand.

**B. Non-wood products**

Non-wood products include fodder, different chemical extractives from leaves and bark, gum and resins, honey and all other products from forests, which are not woods. The major non-wood products being produced in large amounts from forests in Ethiopia are incense and honey.

**4.5. Land evaluation for plantation purpose**

Land evaluation is the assessment of suitability or potential of land for one or more specified land use type. In this context, it involves the determination of the suitability of an area for production plantation establishment.

In a densely populated country like Ethiopia there may not always be much choice for planting sites: foresters may have to accept any reasonable site within the economic transport distance from the populations’ center the plantation is meant to serve. Where there are various sites available, following priorities should be followed in choosing them for planting.

**Open areas:** as a rule, open areas should have first priority for planting, regardless of the objectives of the plantation. These sites are now unproductive (unless they are utilized for grazing) and would be properly utilized if afforested. Secondly, in overgrazed and other denuded areas the risk of erosion may be great if vegetation cover is not restored. Thirdly, clearing and cultivation of these sites for planting does not cost much.

**Areas stocked with shrubs and other vegetation of little value:** The arguments for choosing these sites are nearly the same as for open areas, except that the existing vegetation gives protection against erosion.

**Areas supporting low quality trees or under stocked stands:** These sites can produce saleable products, but the production (in value and volume) would be higher if the areas are converted to a plantation.

Three important aspects of an area are worthy of consideration in land evaluation for forestry.

* Biophysical attributes of the area
* Market and economic aspects
* Environmental impact assessment

**4.5.1. Biophysical attributes of the site**

Biophysical attributes of the site: denotes the totality of biotic and a biotic factors that can affect the survival, development and growth of a given species. The three major physical/abiotic environmental factors are climate, soil and topography. Site assessment in forestry involves the characterization of a given site in terms of these important environmental factors.

* 1. Climate: is the most dominant factor determining the potential of the site for tree growth. The main descriptors of the climate of an area with respect to plantation establishment requirement are:
	+ Rainfall

Total amount of rainfall

Distribution of rainfall – the number of months with rainfall

* + Temperature

Mean annual temperature

Mean temperature of the hottest months

Mean temperature of the coldest months

The coldest or hottest temperature ever recorded – particularly if exotic species is to be introduced

* + Potential evapotranspiration

help to determine the water balance of the site

* 1. Soil

The soil serves three basic functions for tree growth

* Supply of moisture
* Supply of nutrients
* Provision of mechanical support

The following properties of the soil determine its capacity to fulfill its three basic functions and needs to be assessed

* Depth
* Soil structure and texture
* Fertility
* PH

These properties of the soil on the site will be assessed and described qualitatively as follows

Soil depth cm

Very deep 150

Deep 125 – 150

Moderately deep 90 – 125

Moderately shallow 50 – 90

Shallow 25 – 50

Very shallow 0 – 25

Textural group Textural class

Heavy clay, silty clay, sandy clay

Moderately heavy clay loam, sandy clay loam, silty

Medium very fine and loam, loam, silty

Light sandy loam, fine sandy loam

Very light sand, loamy sand

pH

Very acid <4.5

Acid 4.5 – 6.0

Neutral 6.0 – 7.5

Alkaline > 7.5

* 1. Topography

Topography is the relative position and elevations of the natural or human made features of a landscape, used to describe the surface configurations. Topography influences the suitability of the site through its effect on:

* Moisture availability
* Exposure to sunlight, wind and frost
* Soil depth
* Suitability for forestry operations

The topography of the site is characterized through qualitative and quantitative assessment of the following variables:

**Slope:** The angle at which a planar surface is inclined relative to the horizontal. The slope of the site will be measured and grouped in to the following classes

Slope %

Flat 0 – 2

Gently slope 2 – 5

Moderately slope 5 – 10

Moderately steep – very hilly 10 – 30

Very hilly – very steep >30

**Aspect:** refers to the general direction of the land surface relative to the sun. Usually expressed as northward or southward

**Ground roughness:** the frequency of obstacles on the ground

**Stoniness:** the frequency of stones or rocks

Stoniness Area cover (%)

No stones or few 15

Moderately stony 15 – 30

Stony 30 – 50

Very stony 50 – 85

Rubble land 85

* 1. Biotic factors

This includes all living organisms existing on the site that can interact with the plantation species.

* Damaging or grazing animals
* Insect pests: like termites
* Pathogenic fungal, bacterial or viral species
* Existing or previous vegetation including presence of problematic weed species

The site will be described with respect to all this biophysical factors so that its capability for tree growth can be determined. It is one of the most important information used in making species choice for plantation establishment.

**4.5.2. Economic considerations**

The economic transport distance of the product

* + 1. Firewood, charcoal, building poles: In many cases, plantations are managed for the purpose of producing both fuel wood and poles. In many areas firewood gatherers have to walk longer and longer distances to get their wood nowadays. To minimize the transport distance, firewood plantations should located as close to villages as possible. Compared with other fuels such as kerosene or charcoal, wood is a rather energy inefficient fuel. Thus it is more economical to transport charcoal than firewood over long distances. Charcoal is commonly transported over 200 to 300 km in many African countries. As between 30 and 50% of the heat value of wood is lost during conversion to charcoal, it may be more economical to use firewood where transport distances are short and transport costs low. As charcoal is easy to transport and handle, it becomes increasingly attractive when transport distances get longer.
		2. Timber plantations: Harvesting and processing of logs are usually more economical in large units. Thus it is advisable to concentrate timber plantations into as large units as conditions permit. The economic transport distance for logs depends on the value of the timber: the distance is shorter for less-valuable general utility timbers such as pine and cypress than for highly valuable hard woods e.g. Aningeria. Again, processed timber can be transported over much greater distances than logs of the same species.
		3. Size of plantation: A plantation area must be large enough to meet the expected demand for produce for foreseeable future. To be able to calculate the area needed for a plantation, we need to know the expected consumption of wood per year and the average growth rate of the species. Industrial plantations should be large enough to provide an economic working unit for the staff allocated to it. A sufficient size would also provide steady work for equipment and machinery used on it. Any plantation site should, as far as possible, allow for expansion in future if required.
		4. Shape of plantation: Shape of plantation is important both in extraction and in protection (especially against fire). For the rational arrangement of these, compact areas are preferred to long narrow areas or areas with irregular boundaries.
		5. Existing or planned roads: Generally it is more economical to use existing or planned public road systems for the extraction of forest produce. This saves a lot of costs on both the construction and the maintenance of roads. In most cases, however, large industrial planting projects are established in rather remote areas. When roads are, thus, constructed by the Forest Agency, the public inevitably make use of them. It is usually difficult to hand over these roads later to local authorities, as they are happy to make use of the roads maintained by somebody else.

**4.6. Choice of species**

Any plantation species should meet the following requirements:

* It should be easy to obtain the seed;
* It should be easy to handle the plants in nursery and plantations;
* The species should preferably be fast growing in the youth so as to minimize the time and cost of weeding.

The choice of species for plantations depends on the objects of the plantation and on the site.

**4.6.1. Objectives of plantation**

Firewood, charcoal: **A high calorific value (=heat value) is desirable as well as absence of sparking and bad smell in burning**. Rapid growth and high volume production are essential, if plantations are established mainly for firewood production, whereas stem form is less relevant. For village woodlots the species should be able to grow with a minimum of tending, and ability to coppice would be required. *Eucalyptus species*, *Acacia species*, *Azadirachta indica*, *Casuarina* species, are among the best choices for firewood plantations.

Poles: The stems should be straight, round and of adequate strength. The trees should be fast growing and able to coppice. Usually plantations are managed for both firewood and pole production. A number of species such as Eucalyptus and Casuarina species are good for both purposes.

Timber: Good stem form is desirable and, besides, the wood itself must have all the qualities needed for the planned end uses. For instance, general utility wood should be light in weight and easy to work and nail: *Cypress, Podo* and *Pines* are good for this. For outdoor construction, resistance against termites and rots is essential: there is no species better than *Juniperus* for this purpose. For high quality carpentry the species should have strong wood with attractive appearance: *Cordia, Aningeria, Pygeum, Olea* species and a number of other species are good for this.

Pulp and paper: Thickness and length of wood fibers, as well as colour of wood are the most important factors determining the choice of species for pulp and paper industries. Pines, which have long fibers, have been widely used in pulp industries, nowadays short-fibred eucalyptus and other fast-growing hardwoods are used for production of certain types of paper.

Soil and water conservation: Desirable characteristics of species for soil and water conservation plantations are as follows:

* Good survival and fast growth on poor sites
* Ability to produce a large amount of litter
* Strong and wide spreading root system with numerous fibrous roots. On sites prone to landslides, deep roots are essential.
* Easy to establish, little need for tending
* Capacity to form a dense crown and to retain foliage year round, or at least through the dry season.
* Resistance to insects, diseases and browsing damage
* Able to improve soil through nitrification
* Some useful forest produce

Some of the possible species are listed below: *Acacia arabica* (dry areas), *A. cyanophylla* (dry areas), *A. melanoxylon* (moist highlands), *Albizzia lebbek* (dry lowlands), various *Eucalyptus* species, such as *E. camaldulensis* (dry lowland), *E. occidentalis* (dry lowlands), *Olea africana* (dry highlands), *Pinus spp*., *Parkinsnia aculeate* (dry areas,) *Psosopis juliflora* (dry areas), *Pithecolobium dulce* (very dry areas).

**4.6.2. The site**

In Ethiopia the main factors which may limit tree growth and choice of species are:

a) Seasonal deficiency of water; which causes slow growth, low yields and, in most serious cases, even death. In areas with severe dry seasons correct choice of species is essential.

b) High temperatures: These may cause evergreen species suffer from excessive transpiration stress during high temperatures in dry season, Again, to minimize heat damages, correct choice of species is necessary.

c) Low temperatures: Frost can damage and kill young plants in coldest places in highlands. For such sites, frost-hardy species must be planted. (E.g. Juniperus, Hagenia, Olea africana).

d) Unfavorable soil profiles with hardpans: Growth may be limited either by the physical inability of roots to penetrate such layers, or by inability of rain-water to enter the soil so that the water is lost to the site by run- off. Before starting large plantations it is necessary to check that the soils are deep enough.

e) Nutrient deficiencies: Phosphate, nitrogen and boron are most commonly in short supply. Fertilizing the most infertile sites.

f) Pests and diseases

**4.7. Plantation site preparation**

Site or ground preparation includes clearing of the indigenous vegetation and cultivating of the ground before planting. The extent of ground preparation for tree planting depends on the climate of the area, vegetation, type of soil and the species to be planted. Generally, in areas where deficiency of water limits plant growth at certain times of the years, a more intensive and thorough preparation is required than in moister areas.

**A. Objectives**

The objectives of ground preparation are:

* To remove competing tree and grass vegetation from the site.
* To create conditions which will enable the soil to catch and absorb rainfall
* To provide good rooting conditions for the trees.
* To minimize the risk of fire.
* To facilitate mechanized tending operations after planting. So far, no mechanized planting projects have been started in Ethiopia.

To sum up, the aim is to give the young trees a good start with rapid early growth, so that there would be no period of decreased growth after planting. Ground preparation and tending operations that are done after planting, form the biggest block of expenditure in the total establishment cost of the plantation. Ground preparation and subsequent tending are interlinked: inadequate ground preparation may greatly increase weeding costs, whereas proper site preparation may decrease need for later tending.

**B. Clearing**

There are different methods of ground preparation depending on:

* the species to be planted
* vegetation cover of the site
* Soils and site conditions

Ground preparation could be done in one of the following ways: manual clearance, mechanical clearance, burning and use of chemicals.

**1. Manual clearance**

This manual clearance is used to fell trees, cut off branches, stock and pile debris. It is suitable in areas where clearance is relatively easy (e.g. grasslands). This method of clearing vegetation can be done any time of the year, required few new skills, needs small capital cost, provide temporary employment to the community and does not have any pollution and damage of soils. However, it is slow and expensive for clearing dense woodland (usually requires 150 man days per hectare). Manual methods are concentrating mainly on:

1. Grass and shrub covered sites: usually only slashing is needed, followed by ground cultivation
2. Bush or forest covered sites

On sites covered with wood vegetation there are two major clearing techniques:

1. Felling where roots are left in the ground, or
2. Stumping where the roots are extracted: uprooting of stumps is necessary where it is planned that there will be subsequent cultivation, often mechanized, requiring the elimination of roots. Manual stumping is the oldest and most common way of doing it.

**2. Mechanical clearance**

It is usually done using heavy crawler tractors or bulldozers and it uproots the tree. This method is suitable for clear scrub woodland and savanna and not suitable for swampy and wet ground. In this method of clearing about 30 to 40 hectare of land can be cleared per day and the machines can be used to pile and stock the debris. It is relatively cheap (about 1/10 of the cost required for manual clearance). However, it needs high capital cost and training and supervision, problem of equipment maintenance, low employment opportunity and high risk of soil damage by compaction are also some of the disadvantage of this method.

**3. Prescribed burning**

It is effective when controlled to clear vegetation and reduce the debris on the site. This method is suitable to clear debris after manual or mechanical clearance. This method is cheap, improves access greatly, result layer of ash which is rich in base nutrients and often kills rats. The risk of getting fire out of control, the result depends on weather conditions, possible loss of organic matter and N from the ecosystem and depress subsequent growth of some species are some of the difficulties using this method of vegetation clearing.

**4. Use of chemicals**

It is usually the use of herbicides which kills a plant by desiccating the leaves, upsetting its hormone balance or interfering with its metabolism. The herbicides are used to kill grasses along planting lines or around planting spots before planting. It can also kill remnant over storey trees. It is effective and cheap under the right condition. However, using of chemical clearance has disadvantages:

* They cannot clear the site of woody vegetation
* Plants and trees are only killed but dead body remains
* They are poisonous and should be handled with care
* They need careful storing, mixing, and applying in order to use safely and at a correct rate
* Both chemicals and instruments should be imported

**C. Ground cultivation before planting**

Soil cultivation is a compromise between the requirements of fast tree growth and that of soil conservation. The general rule holds that the more thoroughly the soil is cultivated before planting, the more vigorously the trees will grow. The more thorough the soil cultivation is, the more there is a risk of accelerated erosion before the trees becomes established. Soil cultivation must, therefore, be adapted to prevailing slope conditions. Methods of minimum tillage are often compulsory. Instead of increased erosion, the successful soil cultivation connected with carefully selected species should decrease erosion. As the canopy closes, the gully formation should stop and the sheet erosion should be minimized.

Planting spots should be free of weeds within a diameter of 60-120cm depending on the species. The size to which planting spots are dug varies with the following factors:

* Species: broad-leaved species need bigger dimension than narrow leafed ones as transpiration is higher for the former & needs to collect more moisture.
* Climate: in arid areas bigger dimension is necessary as it needs to collect more moisture.

Depending on the degree of tillage, soil cultivation can be carried out as spot cultivation, line cultivation or complete cultivation.

* + 1. **No cultivation**

Pines (e.g. *Pinus elliottii*) are sometimes planted in grassland sites by simply digging a hole and inserting the plant into it. This method can only give satisfactory results; if weeds are controlled after planting by frequent slashing. This is not an adequate method of ground preparation for *eucalyptus* and *cypress*. Even *pines* would benefit from a more thorough ground preparation.

* + 1. **Spot cultivation**

It is the minimum standard of ground preparation and usually done in areas of grass. In this case the operation consists of removing with hoe the vegetation for a distance of 60 cm around the planting spots. Spot cultivation or pitting, done manually, is the standard soil cultivation method of highland forestry throughout Africa. Pitting is a minimum tillage method; it reduces the risk of accelerated erosion but it ensures an acceptable initial growth for the seedlings.

Weathering of the soil removed from the pit and weathering of the bottom of the pit is important for the root growth of the planted seedlings. Some nutrient release takes place during the weathering. More important is the softening of the bottom soil. When the rains start, water has a pathway to the soil, to those layers where the roots are aimed to grow. Softening of the bottom of the pit is further enhanced by the short rains. The recommended size of the pit is 40 cm in diameter and 40 cm deep. Pits can be dug with local crow bars. They are sturdy enough to withstand the heavy work. Light hoes have been tested for pitting, but no superior new tool for dry season pitting has thus far been found to replace the conventional crow bar.

* + 1. **Line cultivation**

Line cultivation can be practiced on gentle slopes. To prevent erosion, the cultivation lines should always be worked out along the contours. In favorable circumstances, line cultivation can be done with oxen plows. The average line width can be between 2 and 4 m. Cultivation is done in lines or corridors between the bushes. Since natural bushes are left inside the plantation, stocking of the more productive plantation trees remains low, and high yields cannot be expected from such stands. Line cultivation can be either line hoeing or line plowing

**Line hoeing:** It is applicable in more dense grass areas where a stripe of 1.5 m is hoed along the lines to be planted. This operation provides easier access to the planting spots as well as reducing competition.

**Stripe plowing:** it is used in a more dense grass area using ploughs. It is usually to make two passes one in either direction with a double furrow. A stripe of 1.5-1.8 m (3m) can be done in this way.

* + 1. **Complete cultivation**

Complete cultivation is implemented by working through the soil in the entire plantation site. Complete soil cultivation, followed by regular clean weeding, is the most beneficial soil cultivation method for tree growth. Complete cultivation creates an ideal soil environment for the tree roots: soil becomes soft and well-structured, it has adequate pores-to solids ratio, and there are no competing grasses or other weeds. However, due to the hazard of erosion, complete cultivation cannot be carried out on steep slopes; it is possible only on flat undulating slopes or on flat lands. Complete cultivation could be either clean hoeing or complete plowing:

**Clean hoeing:** For tree species like *Eucalyptus* and *Cupressus*, which need maximum clearance a complete hoeing of the area using a simple hoe by hand. This is done in areas where labor is sufficient.

**Complete plowing:** It is an expensive operation and is usually applied for research purpose plantations

**D. Special ground preparation techniques for difficult sites**

Special ground preparation techniques that are applicable to waterlogged sites and to sites where water conservation measures are needed for the establishment of a forest plantation:

1. **Waterlogged sites:**

Ploughing and mound-making: Clayey waterlogged sites are first ploughs or hoed throughout.

Drainage systems: If the site is badly waterlogged, e.g. a large marsh, a drainage system with trenches may be required, before tree planting is done.

1. **Sites where soil and water conservation measures are required before planting**

In areas with a marked dry season the surface soil layers tend to become dry and compacted and less able to absorb the rainfall at the onset of the rainy season. A dense ground cover of permanent vegetation is the best form of protection in such environments.

Contour ploughing: This method is practiced on erodible lands with gentle slopes. Shallow or deep ploughing can be continuous on slopes up to 5% where the soils are permeable. Slopes up to 15% can be ploughed in 2-2.5m wide strips spaced 5-6m apart.

Dry stone walls: These are laid out along contour lines. The walls are constructed from rocks and should not be more than 60 cm high.

Contour bunds and ditches: These serve to check surface runoff and to channel excessive water into natural streams or waterways.

Terraces: are also called contour steps, or ridges or bunds. The objective of terraces is to retard and collect all runoff water from between terraces, thereby preventing erosion.

Half-moon shaped truncheons (Micro catchments): This is a method of planting trees on eroded, permeable soils in dry areas.

**4.8. Determining plant spacing**

Spacing of trees is a compromise between expected yield and plantation establishment cost. If the main purpose is to produce biomass fast and in large quantities, high planting densities will ensure this. On the other hand, an increase in the planting density quickly raises plantation establishment cost. If the spacing is reduced, for example, from 2.5 x 2.5 m (1,600 trees per ha) to 2.0 x 2.0 m (2,500 trees per ha), the need for pits, seedlings, labor and the cost of plantation establishment are raised by 56 %. Since the yield increment at high densities is slow (for additional trees planted, the extra yield per ha is small), practical plantation establishment must adapt to a compromise in the planting density.

The rule of high density does not hold if quality instead of quantity in the harvested timber is regarded as important. High densities in forest plantations result in thin stems, not in thicker poles needed for demanding house construction. If large harvests of thick poles are required instead of large harvests of slender poles, wider spacing can be used. Selection between the two options: i) denser spacing shorter rotation, and ii) wider spacing - longer rotation, is therefore dependent on the requirements and needs of the harvest.

The most common spacing throughout African plantation forestry is 2.5 x 2.5 m, or 1,600 trees per ha. In rotations of about 10 years, this density ensures an acceptable mean annual increment for eucalypts. Another common spacing, which is most frequent in Ethiopian fuel wood plantations, is 2 x 2 m, corresponding to 2, 500 trees per ha. This denser spacing enables somewhat shorter rotation, but it has also been found to be practical in eliminating some of the need for beating up. Even if the target of stocking is only 1,600 trees per ha, it is often advisable to pit at spacing of 2,500 pits per ha, and to plant and beat up the plantation twice at this spacing. Even if pitting planting and beating up have been done carefully, in the highlands there remains a normal dieback of the seedlings. This may result in the final stocking of somewhere between 1,200 to 1,600 trees per ha, which still can be regarded as a success. It is therefore important to notice that pitting density and final stocking are two different matters. Pitting should be done at a target density of 2,500 pits per ha, but target stocking could be only about half of that.

Spacing between seedlings to be planted should be determined for each tree species as it has got effects like:

1. **Silvicultural effects**

The rate of growth: generally closer spacing results in slow growth and widely spaced trees produce greater individual growth especially stem diameter

Shape of the tree is also affected: trees growing at a wider spacing have rapid growth and this brings about large branches and tapering stem form. Whereas, trees growing at a closer spacing grow slowly but have more or less cylindrical stem form and light branch

Strength of timber: generally trees growing at a closer spacing have strong timber

1. **Economic effects**

Cost: smaller spacing is costly because it needs more number of seedlings, pots and labor

Choice of final crop: close spacing enables phonotypical section wider method of weeding for mechanical weeding wider spacing is advantageous.

**4.9. Digging of planting holes**

It is not always possible to dig planting holes (Pitting) in connection of lining-out. Often boles are dug at the same time as spots are hoe, in advance of planting. If pines are going to be planted to an uncultivated site, it is usually advisable to dig holes in advance. Often these “pre-dug” holes have given better results than planting into holes which were dug at the time of planting. The reason is that more fertile layers of topsoil and possibly some ashes (if the site was burned) are washed down to the bottom of the hole. Furthermore, sun and rain cause the hole sides to “weather”; the sides become uneven, rough and easier for roots to penetrate.

**4.9. Planting**

**4.9.1. Planting season**

The optimal time for tree planting in Ethiopia is at the start of the main rainy season. The sooner the planting can be started at the first regular showers, the better the survival of the seedlings during the coming dry season. The plants should have their roots penetrating into the subsoil during the rains. Therefore, the recommendable planting season clearly ends before the completion of the rainy season; in fact, planting should be finished around 8 weeks before the dry -reason starts.

Within the planting season the schedule is usually so tight that planting must be carried out every day, from dawn to dusk. If it is possible to choose, it is preferable to plant when the sky is overcast, when humidity is high and wind velocity low. These conditions are met during the mornings and late afternoons, as well as after a shower. Generally the following should be considered to have good seedling survival and growth after planting

* Time of planting is usually at the commencement of the rainy season.
* Plant trees when soil moisture levels have returned to field capacity
* Plant always on cloudy day
* Plant balanced plants which have been well watered before leaving the nursery.**4.10.2. Planting steps**

Before the seedlings are planted they should be thoroughly watered. The main steps of planting are described as follows:

* Check that the pit meets the size requirements (40 cm in diameter, 40 cm deep) and that enough soil is found to fill the pit. If needed, improve the pit and collect extra soil from above the pit.
* Fill the pit by spreading the original topsoil to the bottom of the hole and then the rest of the soil on top. This order places the nutrient rich soil at the roots.
* Remove the plastic film by cutting it with one cut from top to bottom with, for instance, a razor blade.
* Insert the seedling into the soil to the level of its root collar. Take care not to damage the earth ball.
* Cover the root collar with a soil layer of 2-3 cm to allow for settling.
* Firm the soil around the seedling by pressing which foot. This is to avoid air pockets around roots.
* Fill the pit to ground level. Otherwise, pit depression retains water which causes localized water logging.

 **4.10.3. Survival count and replacement planting.**

Survival count is done to inspect how successful the planting was and to see whether replacement planting is necessary. Survival count can be done already 2 to 3 weeks after planting so that replacement planting, if needed, can be carried out during the same rainy season as the main planting. The common method of survival count is recording on a form. A form is prepared in advance, with following headings:

|  |  |  |  |
| --- | --- | --- | --- |
| Line No. | Healthy plants No. | Damaged/Sick No. | Dead/missing |
| 1 | 17 | 6 | 10 |
| 2 | 14 | 4 | 15 |
| . | . | . | . |
| . | . | . | . |
|  | 31 | 10  | 25 |

The inspector moves along the row of plants, marking every plant into the appropriate column using the five-bargate method. In the end healthy trees are summed up in the bottom of the column and the same is done with the other 2 columns. Survival percent is then obtained from:



If the survival percent is less than 80% replanting is necessary. Replanting should be done not greater than a year after planting. The plants should be strong to avoid disorders. Planting is rarely so successful that full stocking is achieved at first try. Normally, a number of seedlings die during the first dry season, and the replacing of dead seedlings with new ones is compulsory. Beating up needs to be done twice and sometimes 3 times.

The first beating up is done at the end of the rainy season during which the initial planting takes place. About 5 to 10 % of the seedlings in the nursery should be reserved for this purpose. Sometimes, this replanting is enough to raise, the stocking to an acceptable level.

The most important beating up takes place in the second year after the planting. During this final beating up the pits for beating up are planted first. The best and most vigorous seedlings can catch up the growth advantage that the 1-year old seedlings have in the field.

The third beating up is done at the beginning of the second main rains after the planting. During this final beating up, it is still more important to use large enough seedlings to enable catching up the growth difference. The third beating up is optional and is decided upon compartment by compartment.

It is also possible to do the beating up during the short rains. This requires specially-timed seedling production in the nursery so that there are seedlings available at the beginning of short rains, around February and March in the main parts of the highlands. Since the short rain cannot be practiced on a large scale, but in special compartments only.

**Chapter 5. Tending operation in plantation forests**

 **5.1. Weeding**

Weeds, mainly grasses, are the main obstacles in plantation forestry for not achieving the potential timber productivity. This is particularly the case with *Eucalyptus* fuel wood plantations. It is a known fact that the growth of *eucalyptus* is inversely proportional to the growth of weeds.

1. **Types of weeding**

Weeding can be done completely or partially. As far as fast tree growth is concerned, complete weeding is the best. It ensures maximum growth of the trees at the expense of the competing vegetation. Complete weeding, however, is expensive to carry out manually. It is best suited to even, soft soils, and to agricultural lands and to mechanized methods. In areas that are prone to erosion, complete weeding may lead to erosion, and is not preferable.

Partial weeding can be done either in strips (between the rows of trees) or in spots (around the saplings). Weeding in strips is possible, for instance, on slopes, along contour lines if the trees have been planted in rows along the contours.

Spot weeding is the minimum type of weeding, and the most common way to weed. The diameter of the spot should be 75 to 100 cm. If the size of the spot is smaller, the grasses will soon cover the soil and suppress the tree growth.

Weeding can be done either manually, mechanically or chemically. Manual weeding is the standard way in Ethiopian condition. It is best done with a sharp-ended hoe, when the soil is still moist. By hoeing the area from the perimeter to the center, the grass roots are cut deep but the tree roots are not damaged. The cut, loose grass roots must be removed since they may start rooting in the soil when the next rains come.

1. **Time of weeding**

The growth of grasses is fastest during the rainy season. Therefore, the first weeding should begin immediately after the planting is finished, at the end of the rainy season. The first weeding should be so efficient that it keeps grasses low until the short rains. If the grasses have grown large enough to suppress the saplings, the area must be cleared before the short rains. The next flush of weeds takes place at the time of the short rains. The purpose of the second weeding is to free the seedlings to grow until the following main rains. The third weeding is needed after the second main rains, around September to October. Provided the saplings have now reached a satisfactory height, this weeding is normally the last that is needed. The canopy closes during the second growing year, and weeds no longer seriously compete with the trees.

**5.2 Thinning**

Thinning is the process of removing part of a standing crop to allow the remaining trees to grow at their optimum rate to reach the required size by the object of management for the crop within the period of rotation

1. Degree of thinning: depending on production target the degree of thinning varies. For example for a soft wood crop planted at a rate of 1370 stem/la
* The first thinning the number is reduced to 990 (+or-10%) stems/ha
* Second thinning - to 570- 640 stems /ha
* Third thinning - to 300 - 345 stems/ha
1. Thinning cycle

Thinning cycle is the period between two consecutive thinning. For fast growing it should be shorter. But for long rotation crops many thinning should be carried out depending on production targets & rotation period of the special, thinning should continue until the juvenile portion is greatly reduced. Consideration should also be given to the following while planning thinning

* market condition
* availability of fund
* availability of labor
1. Thinning yield

Thinning has got economic and growth importance

* economically the thinning yield contributes to the total production expected at the end of the rotation
* growth - the remaining trees are favored
1. Selection and mapping of thinning in the field

After deciding the size of a thinning plot and no. of trees to be left/ha the procedure for thinning is as follows

* Start at a given corner of the plot
* Determine the plot
* Count the no. of trees/ plot
* Deduct the number of stems to be left after thinning
* Move through the plot and select the tree to be marked but in the following order.

**5.3.Pruning**

Pruning is the removal of live or deal branches or multiple leaders from the standing tree for the improvement of the tree or its timber. Some tree species such as *Eucalyptus, Aningeria* undergo natural pruning where by the branches will die or shed. Whereas most conifers don't naturally prune, hence artificial pruning

1. **Objectives of artificial pruning**
* Production of knot - free timber
* Prevention of dead knots
* For the production of poles free of irregularities especially for transmission poles
* Removal of dead, broken or diseased branches to prevent entry of rot in to the stem.
* Correction of the form of the stem by removing multiple leaders
* Improvement of appearance of the tree
1. **Types of pruning**

*Access pruning:* it is done especially for supervision by removing obstruction. It is done before the 1st thinning.

*First high pruning:* it is done after the first thinning. In this case half of the trees height is made clear of branches.

*Second high pruning:* It is done after the second thinning for trees that will reach to final harvest. In this case also half or the trees height should be free of branches.

**5.4. Harvesting**

Harvesting described as all operations required to get wood from the forest.