Maintenance of vegetation

This Section gives detail on certain aspects of roadside vegetation maintenance, and complements the practical guidelines given in Section 5 of the *Site Handbook*. This applies to all roadside vegetation, whether it originated from bio-engineering works or another plantation programme, or from a natural forest type.

Planning the maintenance of roadside vegetation is covered in detail in Section 5.2 of the *Site Handbook*.

3.1 INTRODUCTION

Vegetation on roadsides is a long-term management task. The 'maintenance' of vegetation in engineering is thought of as 'management' in forestry, horticulture and agriculture.

Vegetation must be maintained in order to maximise its engineering contribution, its productivity and its appearance. Most operations are similar to normal forestry practices, but there are some particular needs for bio-engineering which are specific to the road sector.

The management of vegetation is part of roadside support maintenance[1]. The two categories of maintenance are defined as follows.

- Routine maintenance is required continually on every road because of environmental degradation, whatever the road's engineering characteristics or traffic volume.
- Preventative maintenance is required to adapt the road to the changing nature of the slopes and streams (*i.e.* to the geophysical environment).

The maintenance tasks for vegetation can be listed according to the intervention frequency (as for on-road maintenance). In this manual, those tasks specifically related to vegetation are considered in detail; other aspects of maintenance in roadside areas are not covered (such as cleaning slope drains, checking structures, *etc.*). Nor is emergency maintenance covered.

To some extent all bio-engineering activities are covered by preventative roadside support maintenance. However, within this category some long-term maintenance requirements fall into routine operations because they are continuous or very regular, or require frequent checks.

In general, lengthmen can carry out *routine maintenance* activities and gangs should carry out *preventative maintenance*. However, the mode of operation depends on the scale of each site and should be kept flexible.

Routine maintenance

Routine maintenance involves simple protection and care of plants, such as weeding, mulching and grass cutting. The normal activities are:

- protection of planting sites from grazing, theft of firewood and timber, and fire;
- weeding;
- mulching;
- grass cutting.

Watering is usually carried out only if a long dry period has followed immediately after site planting, or where bio-engineering works have deliberately been carried out before the start of the monsoon rains.

Guidelines on each of the tasks above can be found in section 5.3, page 118, of the *Site Handbook*.

Preventative maintenance

Preventative maintenance is more complex than routine maintenance. Larger plants (shrubs and trees) require pruning and thinning. Pruning is the removal of the lower branches of large plants. Thinning is the careful removal of whole shrubs and trees to allow more light to penetrate. All forest areas must be thinned on a recurrent basis. Under this long-term management of vegetation comes the repair and replacement of vegetation structures, and the removal of unwanted large plants. The usual activities are:

- thinning of shrubs and trees;
- repair of vegetation structures: *e.g.* repairs to palisades, fascines, brush layering and turf;
- vegetation enrichment;
- removal of unwanted shrubs and trees.

Guidelines on each of the tasks above can be found in Section 5.4, page 121, of the *Site Handbook*.

3.2 STABLE VEGETATION COMMUNITIES

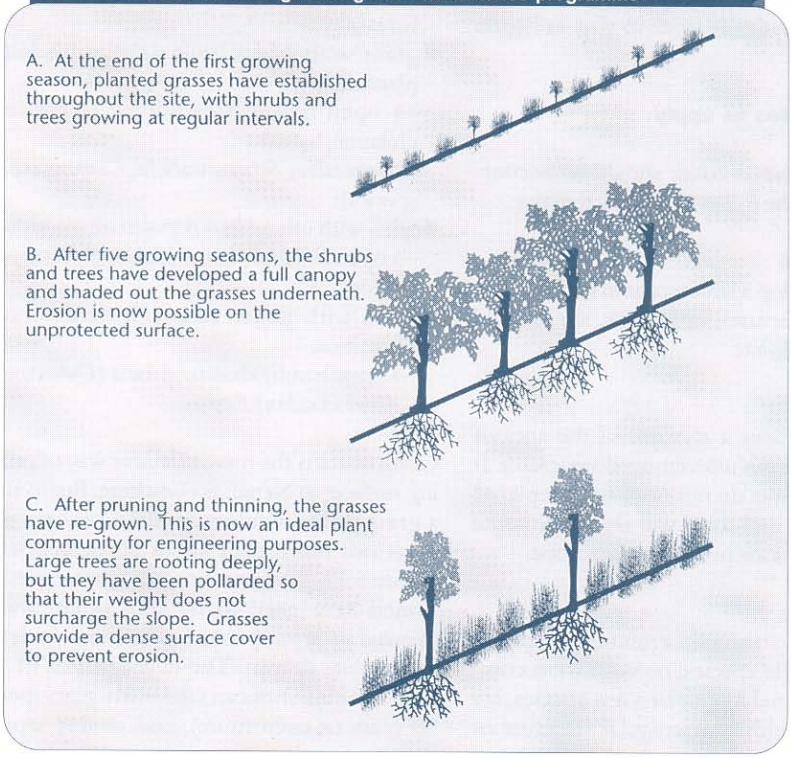
Vegetation development

Many natural vegetation communities[2] do not display the desired engineering properties for surface protection or slope stabilisation. This is because vegetation systems do not evolve specifically for these purposes. Indeed, some areas of apparently well-protected forest actually cover slopes with problems of erosion and shallow landsliding. Protecting vegetation alone does not solve many of the erosion problems that arise when a canopy develops but there is sparse ground cover. For this reason, some parts of the Nepal middle hills which are covered in heavily degraded forest and scrub actually have less ero-

[1] *Definition of Maintenance and Maintenance Activities*. Department of Roads, Marg 2051 (November 1994).

[2] A vegetation community can be defined as 'an established group of plants living more-or-less in balance with each other and their environment; the group can be either natural or managed'.

Figure 3.1: Typical development of plant communities under a bio-engineering and maintenance programme



sion than some areas with a dense, high forest canopy. Pine forest is notorious for providing the conditions where erosion can occur underneath large trees.

If the right balance of plants is to exist for engineering purposes, it must be designed and implemented specifically for each site, and then managed in such a way as to maintain the desired engineering functions. Left to their own devices, most bio-engineering sites would not immediately develop a stable arrangement of plants. Most of the species first populating a site are pioneer plants, which cannot survive in a community of other plants unless they are helped in some way, such as by reducing competition. In particular, grasses usually need a lot of sunlight to thrive: while this is available on newly planted sites, it diminishes as the canopy develops; however, grasses provide excellent surface protection and so are very important constituents of most bio-engineering sites. The theory of vegetation communities and competition is given in Chapter 1. Figure 3.1 shows the progression of plant development diagrammatically.

Keeping a vegetation community healthy requires careful maintenance. As the trees grow, their canopies spread and reduce the light reaching the ground. But most grasses (and many shrubs) require full sunlight to grow well, and die rapidly if they do not get it. This leads to a canopy of trees with a poor ground cover.

An ideal bio-engineering vegetation community is shown in Figure 3.1(c). It has the following features:

- Large trees that root deeply, giving maximum anchorage. In this example they have been pollarded[1] so that their weight does not surcharge the slope, but they could have been coppiced[2].
- Shrubs forming an intermediate (understorey) level, with strong, woody roots that are shallower than the tree roots.
- Large clumping grasses (like khar) to provide a thick surface cover to prevent erosion, with a dense network of fibrous roots close to the soil surface.

[1] Where the main trunk of a tree is cut off, usually two to three metres above the ground, to allow new, smaller, shoots to grow.

[2] where the trunk of a tree is cut off about 30 cm above the ground to allow new shoots to grow from the stump.

The central aim of vegetation maintenance is therefore to 'engineer' the plants so that they provide a community as close to that in Figure 3.1(c) as possible.

General principles to apply

Long-term vegetation cover should be encouraged to develop the following characteristics.

Mixed structure

This aims to develop a structure as in Figure 3.1(c) (an irregular structure) with trees, shrubs and grasses on a single site.

Mixed age

This aims to achieve a mixture of the ages of plants on one site (an uneven-aged structure). It means that all plants do not need to be replaced at the same time and there will always be some strong, healthy plants protecting the slope.

Mixed species

The aim here is to maintain a mixture of species on one site. Single species, or vegetation communities dominated by one or a few species, are unlikely to have either an irregular structure or uneven ages.

Low maintenance

The aim is, as far as possible, to establish a vegetation community that does not need too much maintenance. This means moving towards long-term stability in terms of the vegetation community. For example, aim for: a mixture of species which can live together indefinitely; species that can regenerate naturally (without planting); species that do not grow too fast or too tall (less need for frequent cutting and removal); species that live longer, *etc.*

Natural progression

In bio-engineering it is often necessary to start with pioneer species and move towards a climax community (these terms are defined in the box overleaf). Examples of this include:

- grass with tilka/dhanyero (*Wendlandia puberula*/ *Woodfordia fruticosa*) scrubland →open mixed sal (*Shorea robusta*) forest (eventually → open mixed tropical hardwood forest);
- grass with khayer/sisau (*Acacia catechu*/*Dalbergia sissoo*) plantation → open mixed sal (*Shorea robusta*) forest (eventually → open mixed tropical hardwood forest);
- grass with khote salla (*Pinus roxburghii*) plantation → open mixed broadleaved forest (tooni, chilaune, katus) (*Toona ciliata*, *Schima wallichii*, *Castanopsis* species);
- grass with utis (*Alnus nepalensis*) plantation → open chilaune/katus (*Schima*/ *Castanopsis*) forest;
- grass with gobre salla (*Pinus wallichiana*) plantation → open banjh/khasru/gurans (*Quercus*/ *Rhododendron*) forest.

Grass cover is the most effective way of protecting surfaces in Nepal, as elsewhere. But to sustain a grass cover requires an open canopy, which gives not more than about 50 percent shade. Hence for bio-engineering, the forest types mentioned here need to be kept open, and not allowed to develop into dense climax forest with a complete canopy. The development of these final communities can take many years (perhaps 50 years or even more), and so this aspect of maintenance is truly long-term management.

In most vegetation types, an open canopy of forest with grasses in between is not a naturally occurring condition. There is usually a tendency for the trees to close canopy and shade the grasses out, in favour of other, more shade-tolerant understorey plants (but less effective than grasses for surface protection). As a result, regular maintenance of the site will be required to ensure that the balance of vegetation remains as desired.

3.3 MANAGEMENT OF GRASSES

Management of grasses is part of routine maintenance. It is a small-scale management operation that needs to be undertaken only once per year. In small areas, where extensive growth during the growing season impedes the vision of drivers and pedestrians, it should be undertaken monthly.

Grass management entails cutting the stems about 150 mm above the ground, using a karauti or hasiya (sickle). The material produced can then be used either to mulch the surface, or can be removed for mulching elsewhere, or taken for

fodder, thatch, fibres or any other potential use. Stems should be cut only after the seeds have fallen: it should not be done before the beginning of Magh (mid January) but can be undertaken any time in Magh or Falgun (mid January to mid March). See Section 5.3, page 118, of the Site *H*andbook for details.

PIONEER AND CLIMAX SPECIES

Pioneer or colonising species. These are the first plants to appear on bare ground and are naturally adapted to living on sites with harsh conditions.

Examples are:

- grasses: babiyo (*Eulaliopsis binata*), dhonde (*Neyraudia reynaudiana*), kans (*Saccharum spontaneum*), khar (*Cymbopogon microtheca*);
- shrubs: areri (*Acacia pennata*), bhujetro (*Butea minor*), keraukose (*Indigofera atroturpurea*), saruwa/bihaya (*Ipomoea fistulosa*);
- trees: bakaino (*Melia azedarach*), khayer (*Acacia catechu*), salla (both *Pinus roxburghii* and *P. wallichiana*), sisau (*Dalbergia sissoo*), utis (*Alnus nepalensis*).

Most of these species require full sunlight in which to grow, and they are relatively short lived. ***These plants are ideal for establishing on new sites.***

Climax community species. These are plants that can form apparently permanent natural forest or natural vegetation. They tend to require better sites to grow, and to grow more slowly. Within their ranges, they will grow in the same sites as the pioneers, but not until the pioneers have grown up and provided shade and other site improvements.

Examples are:

- grasses: amliso (*Thysanolaena maxima*), dangre khar (*Cymbopogon Pendulus*), padang bans (*Himalayacalamus hookerianus*);
- shrubs: bainsh (*Salix tetrasperma*), simali (*Vitex negundo*), sajiwan (*Jatropha curcas*);
- trees: chilaune (*Schima wallichii*), katus (*Castanopsis* species), lankuri (*Fraxinus floribunda*), sal (*Shorea robusta*).

These species are usually tolerant of some degree of shade, especially when young. They may also be long-lived. ***These plants should be encouraged when they start to appear on established sites, or they can be planted between existing plants.***

In most species, cutting encourages the grass plants to remain vigorous and to put up new shoots. Grasses grow from what are termed 'intercalary meristems'. This means that growth occurs through cell division at the bases of leaves and stems. This makes them fundamentally different from shrubs and trees, which grow from the tips of the branches or shoots (called 'apical meristems'). This is why it is possible to cut grass shoots without affecting the growing points; whereas with most woody plants, cutting the shoots can seriously affect the growth.

In many parts of the world, it is common to burn grassland in order to remove the old, coarse stems and leaves, and encourage a flush of new, tender shoots, which are more palatable and nutritious to foraging animals. In Nepal this is often done in the dry period at the end of the winter. While this is a valid operation on stable areas of extensive grassland, it should never be permitted in roadside areas. The main reason is that it kills larger plants, such as shrubs and trees. In recent years it has also been discouraged or banned in many countries because of the wider ecological damage caused, both by the fire killing insects and small animals, and destroying their habitats, and because of the perceived global problems of rapid carbon release.

In areas around side drains, grasses must always be cut, ideally using a karauti or hasiya (sickle), and must never be pulled out. Large grasses cannot be pulled out by hand in any case, but small plants can be. This can be very damaging to the toe of a cut slope.

3.4 INTRODUCTION TO THE MANAGEMENT OF SHRUBS AND TREES

Under both routine and preventative roadside support maintenance, there is a variety of ways of managing shrubs and trees. Routine operations are required mostly in the first year or two after planting. Preventative maintenance operations are not required until about five years after planting. Section 5.4, page 121, in the Site *H*andbook 'Pruning and thinning of shrubs and trees', gives a simple practical guide. What follows explains in more detail the optimum management procedures for large and complex sites.

Early management

Early management (or maintenance) of shrubs and trees aims to establish the plants as quickly as possible. It is important that the plantation site is protected from grazing animals, people cutting fodder and firewood, and from fire. Small seedlings are particularly susceptible to damage.

There are basically two methods of protection. The easiest in the short term is to employ watchers to police the site throughout the day, to chase away unwelcome visitors. In many roadside areas this may be the only solution. Some road sections are subject to grazing from enormous numbers of animals. Often it is the physical damage from hooves, especially those of cattle, which do more damage than the actual grazing.

The harder, but in the longer term more rewarding, method of protection is to work with the road neighbours (local people) to gain their respect for the vegetation planted to protect slopes and their participation in its wise management. If there is a definite benefit for the people, then they will often respond favourably. Ways of doing this are given in detail in Chapter 5 of this volume. It has been achieved successfully in many parts of Nepal.

In areas where there are well defined community structures, liaison with the local people seems to have more success. Where many people have recently moved into an area from elsewhere, there is often not the societal cohesion necessary for the respectful management of resources, which are perceived to be common property. One result of the rapid expansion of Dhankuta town in the 1980s, for example, was unrestricted grazing, which damaged food crops as well as roadside bio-engineering works. Attempts to work with the graziers and firewood cutters of Barghat (Nawalparasi), also in the late 1980s, came to nothing. Site watchmen were deployed instead, and chased enormous numbers of animals away from the site. This increased from about 150 cows, 500 goats, 750 monkeys and 10 people per month during the dry season, to about 5,000 cows, 12,000 goats, 1,000 monkeys and 500 people per month during the monsoon (when all the cultivated land was growing rice)[1]. Despite these examples, there are many areas where liaison with local people has given rise to community groups and individual farmers making significant contributions to the quality of roadside vegetation. This is elaborated in Chapter 5.

Other early maintenance operations amount to weeding and mulching. Weeding is often needed in the first few years of growth to reduce the competition for the planted species, and to ensure that the site is not invaded by shallow-rooted annual species, which do not contribute the required engineering functions.

Mulching is usually done at the same time as weeding, and in fact the weeds can often be used as a mulch. Dead plants or compost are placed in a broad circle around each planted seedling. This helps to keep the rooting zone cool and moist, thereby improving the conditions for growth.

Watering is not a normal maintenance activity, but can be undertaken in exceptional circumstances to improve growth during dry periods. Difficult sites can be successfully planted before the start of the rains if the site can be watered regularly. Plants thrive in the combination of intense sunlight and adequate soil water; in addition, they make use of the annual nitrogen flush before the leaching caused by the first main rains.

Details of these maintenance operations are given in Section 5.3 of the Site *H*andbook (page 118).

Later management

After about five years, the management of shrubs and trees changes completely. Weeds are no longer a problem and protection is less critical. Grazing animals can no longer damage the plants, but in some locations heavy lopping for fodder or firewood can be damaging. Instead, the major maintenance consideration is to stop the canopy of larger plants becoming too thick and suppressing the lower plants (mainly grasses), which protect the surface.

The longer term management of shrubs and trees aims to:

- increase light penetration through the canopy to the ground so that plants (especially grasses) can grow better;
- keep a vigorous mixture of plants of various sizes and shapes;
- improve the mixture of ages and species in the plant community on the site;
- reduce the weight surcharge and wind resistance of large trees.

[1] *Banko Janakari*, 1992. 3 (3): 43-46.

Figure 3.2: Characteristics of vegetation canopies requiring thinning

Canopy characteristics	Method of assessment *
1. If the canopy cover (crown cover) is greater than 50 percent	Visual or spherical densiometer
2. If there is a tree canopy but no shrub layer or ground vegetation layer	Visual
3. If the tree canopy is mostly of a single species or more or less even-aged	Visual or measurement plots
4. If the tree canopy has dead or unhealthy trees in it, or if there are leaning trees	Visual
5. If the site is fully stocked or overstocked with trees	Measurement of basal area or stem counts in plots, or visual
6. If there are large heavy-crowned trees (especially on steep slopes)	Visual

* Descriptions of these methods are given in the box on page 86.

How to decide whether shrub and tree management is needed

If the site has one or more of the features described in Figure 3.2, then the trees and shrubs on the site will need management of some kind.

Measuring canopy cover and stocking

The percentage canopy cover is a good indicator of the amount of light reaching the ground. For bio-engineering purposes, the canopy cover need not be more than 50 percent. If it is greater than this, some canopy can be safely removed.

There are various ways to measure canopy cover.

Visually

Walk through the site and estimate at various points the percentage of the sky that is covered by tree canopy. Take the average from a number of points on the site. Note that this method can be quite inaccurate. The estimated percentage varies with the observer, according to weather conditions, season (some trees are deciduous), *etc.*

Spherical densiometer

This is a simple device which enables canopy cover percentage to be more accurately measured (see box on page 86). Note that several readings need to be taken, and the average of these used. Although more accurate than visual methods, this still suffers from seasonal changes. The Geo-Environmental Unit can supply the instrument required.

Another useful indicator of forest condition is a measurement of stocking. This can also be assessed visually, or by measurement (using a wedge prism or sample plots, see box on page 86). Stocking can be measured as stems per hectare or more usefully as basal area. Basal area is the amount of area actually covered by tree stems (as opposed to crowns) per hectare. It can be measured accurately, and is unaffected by seasons, weather, or observer bias. However, its measurement may take a little longer, and is more difficult to do on steep slopes. The Geo-Environmental Unit can supply the instrument required.

Basal areas range from zero to a maximum of about 45 sq. m/ha. Figures greater than 30 sq. m/ha are unlikely to be found. There is a weak relationship between canopy cover and basal area. Normally, anything with basal area > 25 sq. m/ha would have a canopy cover percentage > 80 percent. Sites with a basal area < 10 sq. m/ha would probably have an open canopy (< 50 percent).

3.5 CHOOSING THE APPROPRIATE THINNING OPTION FOR SHRUBS AND TREES

The results of visual assessment or measurement will enable you to answer the following questions (modified from Figure 3.2). If the answer to one or more of the questions is 'yes', then an appropriate management activity, or combination, will need to be selected.

- Is the canopy cover (crown cover) greater than 50 percent?
- Is there a tree canopy but no shrub layer or ground vegetation cover?

Figure 3.3: Determination of pruning and thinning

Assessment criterion	Action required
Does a study of the shrub and tree canopy show that there is not enough light penetrating to allow grass to grow underneath?	If 'yes', then prune fully and address the next question. If 'no', then re-assess the situation in one year.
Has the canopy been opened only by cutting off branches?	If 'yes', then only *pruning* was required. If 'no', then *thinning* is also required.
Can the trees withstand pollarding or coppicing (see boxes opposite)?	If 'yes', use *pollarding* where grazing is a problem, or *selection thinning*. If grazing can be controlled or is not a problem, then use *coppicing* or *selection thinning*. If 'no' then *selection thinning* is required (*i.e.* where shrubs or trees are cut off just above the ground and are not expected to re-grow).

- Is the tree canopy mostly of a single species or more or less even-aged?
- Does the tree canopy have dead or unhealthy trees in it, or are there leaning trees?
- Is the site fully stocked or overstocked with trees?
- Are there large heavy-crowned trees (especially on steep slopes)?

In every case, pruning should be carried out first of all. The bottom branches, up to half the total height of the shrub or tree, should be cut off. For large, mature trees only, branches can be removed up to two-thirds the total height of the tree.

Branches must be cut cleanly, using sharp tools. They are cut as close to the trunk as possi-ble without causing damage, starting with the branches nearest the ground and moving upwards. Where the branch is more than 50 mm in diameter, a small cut should be made under-neath the branch first, before removing it with a cut from above. The bark should never be torn: this can damage the plant badly.

Once pruning is complete, you will need to

METHODS OF ESTIMATING CANOPY COVER AND STOCKING

Visual skills

The best way to build your visual skills for assessing canopy percentage or stocking is to practice. Try going into different sites and assessing these indicators, first visually, and then by measurement. Remember to try this at different times of year. You should find that your estimates gradually increase in accuracy.

***How to use a spherical densiometer** **

- Hold the instrument level in front of the body and at elbow height with your head just outside the grid area.
- Assume 4 equi-spaced dots in each grid square. Count the number of dots in each quarter-square that lie in canopy openings.
- The total number of dots will give the percentage area not occupied by canopy. Subtract this from 100 to give the canopy percentage.
- Make four readings from each spot facing north, south, east and west, and take the average reading of these.

How to measure stocking using measuring plots

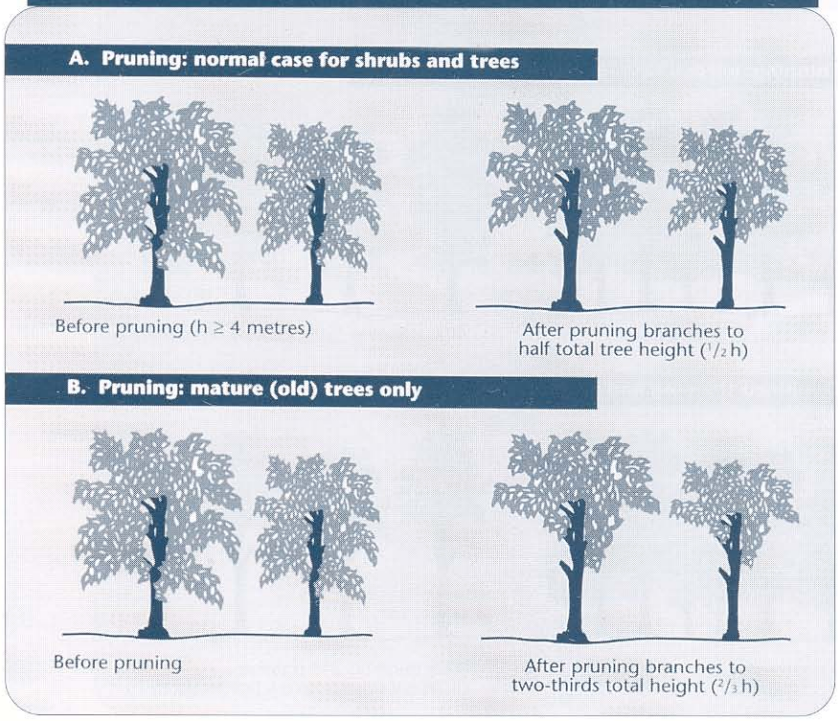
- Lay out a square or circular plot of known size and calculate the plot area (ha).
- Measure the diameter at breast height (1.2 m above ground level) of all trees in the plot.
- Calculate the basal area of each tree using the formula $A = \pi r^2$ where A is the area and r is the radius of the tree at breast height.
- Calculate the total basal area of all the trees in the plot (m^2).
- Calculate the basal area per hectare using the known plot size.
- Calculate the number of stems per hectare.

How to measure basal area using a wedge prism *

- Hold the wedge prism horizontally, at arm's length, with one of the flat sides held to the front.
- Look through the prism at the nearest tree. If the image of the tree as seen through the prism is displaced by more than the diameter of the tree, then do not count the tree. If the image is less than the tree diameter (i.e. there is overlap between the image as seen through the prism and the actual view of the stem) then count the tree as 'in'.
- View all trees in a circle from the measurement point counting those that are 'in'. After a full circle has been viewed, the basal area (m^2/ha) is calculated by the prism factor (written on the prism) multiplied by the number of trees counted.

* The Geo-Environmental Unit can supply the instrument required.

Figure 3.4: Diagrams showing the results of pruning



consider whether the site needs to be thinned, and if so, what sort of thinning. Decide this by asking the following question:

- Has pruning opened the canopy enough to allow sufficient light for grasses to grow under the trees?

If 'yes', then the operation is complete; if 'no', then thinning is needed.

When thinning, there are three options:

- pollarding: a treatment in which the main trunk of a tree is cut off, usually two to three metres above the ground, to allow new, smaller, shoots to grow: this allows new shoots to grow out of the reach of grazing

SPECIES AMENABLE TO COPPICING AND POLLARDING

Species known to pollard

Shrubs/small trees
ambak, areri, armalito, assuro, bainsh, chiya, dhanyero, dhusun, ghurmiso, kimbu, kunyelo, namdi phul, nil kanda, rahar, sajiwan, simali, tilka

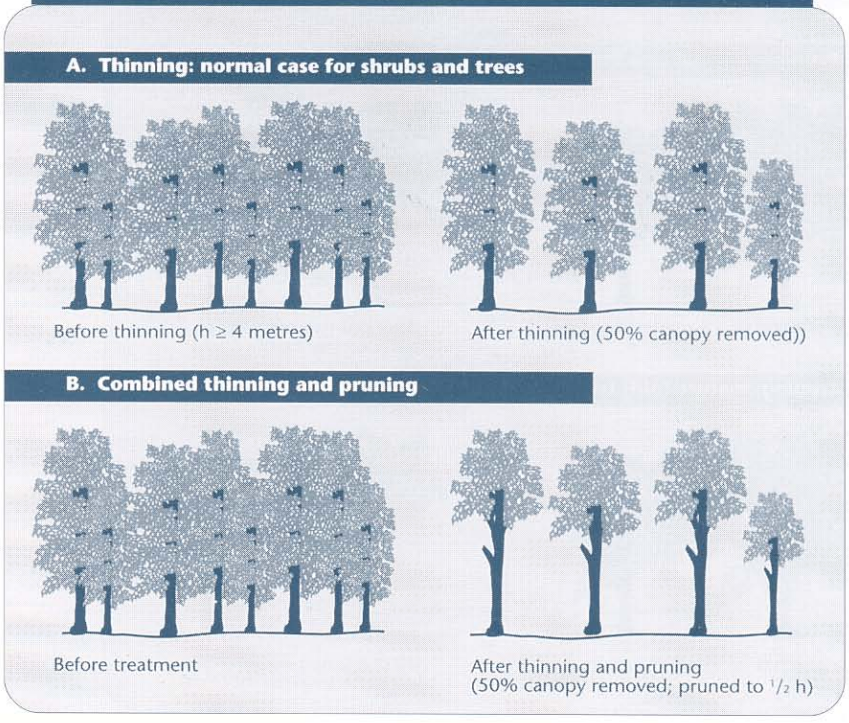
Large trees
acacia (*A. auriculiformis*), bakaino, bange kath, banjhi, champ, dabdabe, deshi katus, dhale katus, gliricidia, ipil ipil, jamun, kadam, kalo siris, kangiyo, kapur, khanyu, khari, khasru, khayer, koiralo, lahare pipal, lankuri, mashala, musure katus, nebharo, neem, okhar, painyu, patle katus, phalant, rato siris, sahijan, sal, sisau

Species known to coppice

Shrubs/small trees
areri, armalito, assuro, bainsh, dhanyero, dhusun, ghurmiso, kimbu, kunyelo, namdi phul, nil kanda, rahar, sajiwan, simali, tilka

Large trees
bakaino, banjhi, champ, dabdabe, deshi katus, dhale katus, gliricidia, ipil ipil, jamun, kadam, kalo siris, kapur, khanyu, khari, khasru, khayer, koiralo, lahare pipal, lankuri, mashala, musure katus, nebharo, neem, okhar, painyu, patle katus, phalant, rato siris, sahijan, sal, sisau

Figure 3.5: Diagrams showing the results of thinning



animals, but not all plants will tolerate this;

- coppicing: where the trunk of a tree is cut off about 300 mm above the ground to allow new shoots to grow from the stump, but not all plants will tolerate this; and
- selection felling: where the trunk of a tree is cut off about 150 mm above the ground, and it is not expected to shoot again.

The ability of a shrub or tree to coppice or pollard depends on the vigour and growth characteristics of the species. Plants commonly lopped for fodder will mostly tolerate it. All those grown from hardwood cuttings will certainly tolerate it. Some plants, such as utis (*Alnus nepalensis*) will coppice only under ideal growing conditions but otherwise will die; it is unlikely that conditions in roadside areas will be sufficiently good to allow this. With many species, large and older trees do not coppice as well as young trees. In these cases, selection thinning is a better option than relying on coppicing.

HOW TO MARK THINNINGS

Mark with paint the trees that should remain, and slash the bark of those which should be removed (once you are sure), according to the following criteria.

1. Remove all dead, dying, fallen, diseased or seriously damaged trees.
2. Next remove trees of unwanted species (note that a mixture of species should be retained if possible).
3. Next remove trees of bad shape (crooked, unevenly branched, *etc*). Note that straight stems are not necessarily required for bio-engineering purposes
4. Next remove trees that are spaced close to each other
5. Next remove trees with large crowns
6. Finally, select remaining trees to leave a variety of sizes and ages, forming only about 33 to 50 percent of the original canopy.

All ***unmarked*** trees can now be removed.

The box on page 87 lists the species known to coppice and pollard readily. In addition, the tables of species in Annex B of the *Site Handbook* page 130, give details on coppicing and pollarding potential, as far as they are recorded, for the bio-engineering trees.

The main advantage of coppicing and pollarding is that it creates a shrub or tree with an extensive rooting system but relatively little weight above ground. This means that the plant provides the optimum reinforcement, anchorage or support, without surcharging the slope. In certain cases, it is possible that the roots die back when the plant is cut above ground, but this is not well researched, certainly in Nepal. Pollarding also has the advantage of the new shoots emerging beyond grazing height.

If the species that require thinning will tolerate coppicing or pollarding, then the engineer has a choice of practice, and the choice can be left to the discretion of the individual. The simplest system, however, is to use selection thinning and remove enough plants to open the canopy.

The questions-and-answers in Figure 3.3 summarise the selection of management options to increase light penetration through the canopy by using pruning and thinning operations. For other purposes (*e.g.* removal of weight surcharge), then the most appropriate solution can be chosen according to the particular species and site.

Once the thinning option has been chosen, go through the site slowly and decide which trees must be cut (see box on page 88). The aim should be to remove 50 to 67 percent of the canopy. When marking the thinnings, also look at the ground vegetation. If there are younger trees and shrubs (regeneration), then it should be possible to remove trees from the main canopy to allow them to develop.

Every site must be assessed individually and it is not possible to make precise rules. Engineers and overseers will learn from experience what is the best range of options to use in each location.

The actual process of pruning and thinning is described in Section 5.4 of the *Site Handbook* (page 121). Figure 3.4 gives diagrams of forests before and after pruning, and Figure 3.5 before and after thinning.

3.6 FURTHER CONSIDERATIONS IN THINNING SHRUBS AND TREES

General

All pruning and thinning operations should be carried out between Poush and Falgun (mid December to mid March), when there is little or no growth.

Regular light pruning is better than infrequent heavy pruning.

Pollarding in the simple sense is uncommon in Nepal. More usual is a combination of pollarding and lopping where all branches are removed, leaving a single, more or less bare stem. This system is very similar to the fodder lopping carried out by farmers on their private trees. It is an acceptable alternative to pollarding.

It is better to coppice (and presumably also pollard) a group of trees together, rather than individual trees within a plantation or forest. If single trees are coppiced, the intensity of light on the cut stump is usually not great enough to encourage very vigorous regrowth. In these circumstances, the stump may die, or only put out weak shoots. If a larger gap is created (a 'coupe'), the increased light will give more vigorous regrowth.

Products

Firewood is the main product from pruning operations. But very little firewood will be produced from plants that have been regularly pruned for several years.

A range of sizes of poles will be produced from thinning, suitable for many uses (building, fences, *etc*).

Much of the cut material will be suitable only for firewood if plants are not straight, or if they are an unsuitable species for timber.

Limitations of pollarding and coppicing

Pollarding and coppicing may be less successful on very dry sites. Also, large and old stems often coppice poorly.

If many shoots grow up from a pollarded stump, they may need to be removed after about five years. Otherwise, the canopy will become dense again, or the plant will again grow too large.

About five years after coppicing, a process of

'singling' may be required. This is where most of the coppiced shoots are removed from the stump, leaving only a single good stem. This can often be coppiced again in later years. More frequent coppicing will encourage a good root system and multiple smaller stems will create better ground cover. This means that tree species can be managed as large shrubs rather than tall trees.

Some species can only be pollarded or coppiced a few times before the plants lose their vigour.

Utis forest

Utis (*Alnus nepalensis*) is easy to establish and is a familiar tree on rehabilitated land between 1000 and 2500 metres. But varied plantations dominated by utis are difficult to sustain. This is because utis is essentially a coloniser, rather than a species that grows in a climax community (a permanent forest type). Also, it is often difficult to encourage a good understorey below utis. Therefore, in utis forest, thinning should always aim to remove utis and leave species such as chilaune (*Schima wallichii*), katus (*Castanopsis* species) and painyu (*Prunus cerasoides*). These species will often appear naturally among utis, but if they do not appear, it is worth planting them in gaps in the utis canopy. In Central and Western Nepal, thinning will eventually change the site from one of utis to a mixture based on chilaune-katus. If there is heavy ban mara (*Eupatorium adenophorum*) invasion, this may need to be cleared in patches to allow trees to regenerate or to be planted. Note that utis can coppice but only in the best sites and usually not very strongly.

Pine (salla) forest

There are two indigenous (local) pine species present in Nepal: khote or rani salla (*Pinus roxburghii*) below 1950 metres; and gobre salla (*Pinus wallichiana*) above 1800 metres. In some afforestation areas there are also introduced pine species, but these are more limited in range. Pines can be the best species to establish on many hot, dry sites, and in places also form impressive natural forest. Unfortunately, there is often very little vegetation underneath and so erosion can still take place in good pine forest. Therefore other species should be favoured. Pines should always be removed if there is a choice between them and another tree. If there is no choice, then other species can be planted. The aim should be for a pine plantation to be changed to one of mixed other species.

The creation of a less even-aged and mixed species forest from an originally pure pine forest is often possible by using natural regeneration. If the pine forest (or plantation) is not heavily grazed and is protected from fires, regeneration of pines and broadleaved species such as chilaune (*Schima wallichii*) or tooni (*Toona ciliata*) will normally occur.

Dry Churia scrub forest

This is dominated by tilka (*Wendlandia puberula*) and dhanyero (*Woodfordia fruticosa*). These are both pioneers but can also form a permanent forest type. However, other species should be favoured and tilka and dhanyero removed if there is another tree species present. Care often needs to be taken to encourage ground cover. In the driest areas, babiyo (*Eulaliopsis binata*) grass is the only robust surface cover that will survive.

In theory the climax vegetation community for these areas is sal (*Shorea robusta*) or mixed tropical hardwood forest. In practice, however, it may take so long to reach this in dry sites that management should aim to sustain a tilka-dhanyero scrub forest with a mixture of other species.

Sisau and khayer plantations

Both sisau (*Dalbergia sissoo*) and khayer (*Acacia catechu*) are easy to establish quickly, even on harsh, open sites. They are often used for bio-engineering at low altitudes. However, plantations of these species often have little ground cover. They should be managed so that other species are preferred. Eventually, sisau or khayer should form no more than 50 percent of the tree population.

Forests on *rato mato*

Red clay soils (commonly known as (*rato mato*), although there are local variants) often require special management. They provide poor rooting conditions for plants, as well as low fertility, and are highly erodible. They occur mostly at low altitudes and carry sal (*Shorea robusta*) forest, which is often degraded. Studies have shown that some shade from trees is important for maintaining a ground cover of vegetation, but that too much

shade impedes the growth of grasses. It is therefore necessary to try to maintain a light or dappled shade. If possible, the surface should receive sunlight for between perhaps two and four hours of the day during the late spring and summer. Large gaps in the canopy must be avoided, and the canopy itself must be kept light. This is probably best achieved by the regular pruning of branches. Protection from uncontrolled grazing is also essential.

3.7 MANAGEMENT OF BAMBOOS

General

The establishment of bamboos often requires care, but after that their management is relatively straightforward.

Most bamboos require stable, moist conditions for early growth. This means that heavy mulching is an advantage for about the first three years. Some foresters advocate the use of a 'nurse crop' of trees, where bamboos are planted in the shade of existing trees, which are felled once the bamboo clumps have become established. In bio-engineering, however, it is more normal to plant the bamboos on bare sites and rely on a thick layer of mulch, which is renewed periodically, to keep the roots relatively cool and moist. If the rhizomes of older clumps have been exposed by erosion, they should be covered with mulch. See Section 5.3 of the *S*ite Handbook, page 118 for details of mulching.

After about three years, large culm shoots start to appear from the rhizome. Once this happens, the plant can be considered to be successfully established. It is also resistant to grazing from this time onwards.

In later years, the large bamboos thrive best with very little shade from trees. However, the smaller bamboos, tite nigalo (*D*repanostachyum intermedium) and padang bans (Himalayacalamus hookerianus) grow best under a light shade. For these species, therefore, it is best to try to keep a light canopy cover.

Thinning bamboo clumps

Large bamboo clumps start to become very dense after about 10 years. It is best to start harvesting well before this stage is reached, perhaps five years after planting. Culms should be removed annually, rather than taking many at one time. A clump is likely to be seriously damaged if all the culms are cut at once, and so this should not be done unless it is intended to kill the clump. Up to 25 percent of culms removed at one thinning, repeated every year, is a useful rule for sustained production; however, for bio-engineering purposes it may be preferable to remove a smaller proportion, so as not to over-stress the clump.

Most culms should be cut when they are mature, which means when they are at least four years old. If material is required for weaving, however, culms of only two years age can be harvested.

Culms must be cut just above a node and one or two full internodes above the ground. This allows the attached rhizome to shoot again before it dies. Farmers usually cut the culms close to the ground to maximise the length of culm, but this can cause more rapid death of the rhizome from which the culm is growing.

Thinning should be done in the dormant season, between Kartik and Falgun (mid October to mid March).

Culms must be cut from the inside of the clump, not just from around the edge. Harvesting from the middle of a dense clump is difficult, but is essential to keep the whole clump vigorous, and to encourage it to increase its size. One method is to cut lines through the clump to allow access to the middle culms.

If large clumps have been neglected, it is best only vigorous young ones. Grass, creepers and shrubs should also be removed if they are impeding growth.