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Thinning Guidelines for Pinus Patula and Pinus
Roxburghii Plantations in Nepal



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Acronyms

CFUG	Community Forestry Users Group
CF	Community Forest
DBH	Diameter at Breast Height
DDC	District Development Committee
DFCC	District Forestry Sector Coordination Committee
DFO	District Forest Office
DoF	Department of Forests
FUG	Forest Users Group
ha	Hectare
IGA	Income Generating Activities
MFSC	Ministry of Forest and Soil Conservation
NACRMLP	Nepal Australia Community Resource Management and Livelihoods Project
NGO	Non-Governmental Organisation
NR	Nepalese Rupees
NTFP	Non Timber Forest Products
OP	Operational Plan
PCC	Project Coordinating Committee
PNG	Papua New Guinea
TOR	Terms of Reference
VDC	Village Development Committee

1 Introduction

Nepal has substantial areas of pine plantation, which with basic management interventions could be used to improve rural livelihoods and support the development of wood processing industries.

The early plantations of *Pinus patula* and *Pinus roxburghii* were established during the 1970s but the bulk of the planting was undertaken during the 1980s and these plantations are now between 14 and 27 years old. They are mostly overstocked, are not growing vigorously and are not providing the benefits that they are capable of providing.

These guidelines are based on decades of international research (as brought together in J. Evans and J Turnbull 2004), and local research in Sindhu Palchok and Kabhre Palanchok undertaken during the last two phases of Australian assistance to the forestry sector in Nepal, most notably Hunt, S M., Dangal, S. & Shrestha, S. (2001) and special studies conducted by the Nepal Australian Community Resource Management and Livelihoods Project (NACRMLP) for the purpose of these guidelines (refer Annex 2).

These guidelines present an overview of thinning as few people in Nepal have experience of the principles involved. They then proceed to discuss the status of the plantations, their present condition, and the purpose of management; and then prescribe thinning regimes that will guide their development towards meeting their stated purpose.

The prescriptions are remedial in nature and so are limited in application to the currently overstocked pine plantations. They are not suitable for younger plantations that have been planted since 1990 or any second rotation crops and these may best be treated according to prescriptions provided within Hunt, S. M., Dangal, S. and Shrestha, S. (2001) which are recreated as Annex 1. If the existing plantations continue to be neglected these guidelines will gradually lose relevance.

These guidelines provide an opportunity for improving rural livelihoods and supporting wood processing industries.

1.1 Why is it Necessary to Thin Forest Plantations?

Thinning is the operation that artificially reduces the number of trees growing in a stand. It is normally carried out several times and starts a few years after canopy closure.

The primary reasons for thinning are as follows:

1. To reduce the number of trees in a stand so that the remaining trees have more space for crown and root development, to encourage stem diameter increment and so reach a usable size sooner.
2. To remove trees of poor form (crooked, forked, basal sweep, roughly branched, etc.) so that all future increment is concentrated only on the best trees.
3. For stand hygiene to remove dead, dying, diseased, and any other trees, which may be a source of infection for, or cause damage to, the remaining healthy trees.

4. To reduce between-tree competition to avoid stress levels, which may encourage pest and disease attack.
5. To favour the most vigorous trees with good form which are likely to make up the final crop.
6. To provide an intermediate financial return from sale of thinnings.

Thinning may also be carried out for a number of minor or only locally important reasons including maintaining light levels beneath a stand to provide vegetation (grass sward) for grazing, encouraging native ground flora and providing poles and posts.

Thinning is a purposeful intervention in the life of a stand to alter its development, and that of the trees that constitute it, to achieve certain objectives.

1.2 Experience with Thinning in the Tropics and Sub Tropics

Compared with information about afforestation techniques, less is known about the effects of thinning and what are the most suitable regimes. This is largely because extensive plantation development in the tropics and sub tropics is more recent and there has been insufficient time to gain adequate experience and to carry out long-term experiments over a whole rotation. There are some detailed studies of thinning and the effects of varying initial spacing, for example, *P. patula* in East Africa, especially southern Tanzania (Borota and Proctor 1967; Adlard 1980).

However, there are two important exceptions where information is not lacking. Some 70 years ago in South Africa, Craib (1934, 1939, 1947) worked on thinning regimes for the subtropical pines, *Pinus elliottii*, *P. patula*, and *P. taeda*. The second case is spacing and thinning research in Queensland, Australia, with *Araucaria cunninghamii*, and *P. elliottii*. which has focused on thinning response and control using stand basal area parameters. Currently in most countries, standard thinning schedules are in operation for important species.

1.3 The Effects of Thinning

Thinning is really no more than an extension of the kinds of changes produced by differences in initial spacing. In fact, for a particular species and site, the current growth of a thinned stand is identical to that of an unthinned one if both have the same stocking and standing volume per hectare, though the unthinned stand will usually be younger (Marsh and Burgers 1973). How a stand reaches a particular stocking and volume, because of initial spacing or due to thinning, does not significantly influence its present rate of growth. Both distance between trees at planting and thinning affect the same environmental factors, which are light, nutrients and water available for each tree to grow optimally.

1.3.1 Physiological Effects

Thinning a stand reduces the number of trees competing for light, soil moisture, and nutrients. For example, after thinning, more light reaches beneath the canopy and there is usually a resurgence of weed growth, increased breakdown of litter, and sometimes epicormic shoots on tree stems. Also the water table may rise and the ground become wetter, since there is temporarily both less demand for soil moisture and less interception of rain by the canopy.

Lessening of competition between trees has three main effects:

1. Lower natural mortality. After thinning, trees near full suppression and death, if still left, are able to continue growing mainly because of greater access to light. Natural mortality of trees in thinned stands is uncommon; trees survive longer and ones becoming suppressed are usually thinned out anyway.
2. Deeper crowns on remaining trees. The shaded lower branches of a tree receive more light and remain alive longer; therefore trees in thinned stands have deeper crowns.
3. Crown expansion. The increased growing space surrounding a tree after thinning induces active growth of shoots, foliage, and roots.

The effects of points two and three above result in a greater photosynthetic area on each remaining tree, thus increasing growth potential. If, however, thinning is heavy and large gaps occur in the canopy, which only slowly become occupied, the total interception of light energy by the stand is less than optimal and some loss in total production could be expected.

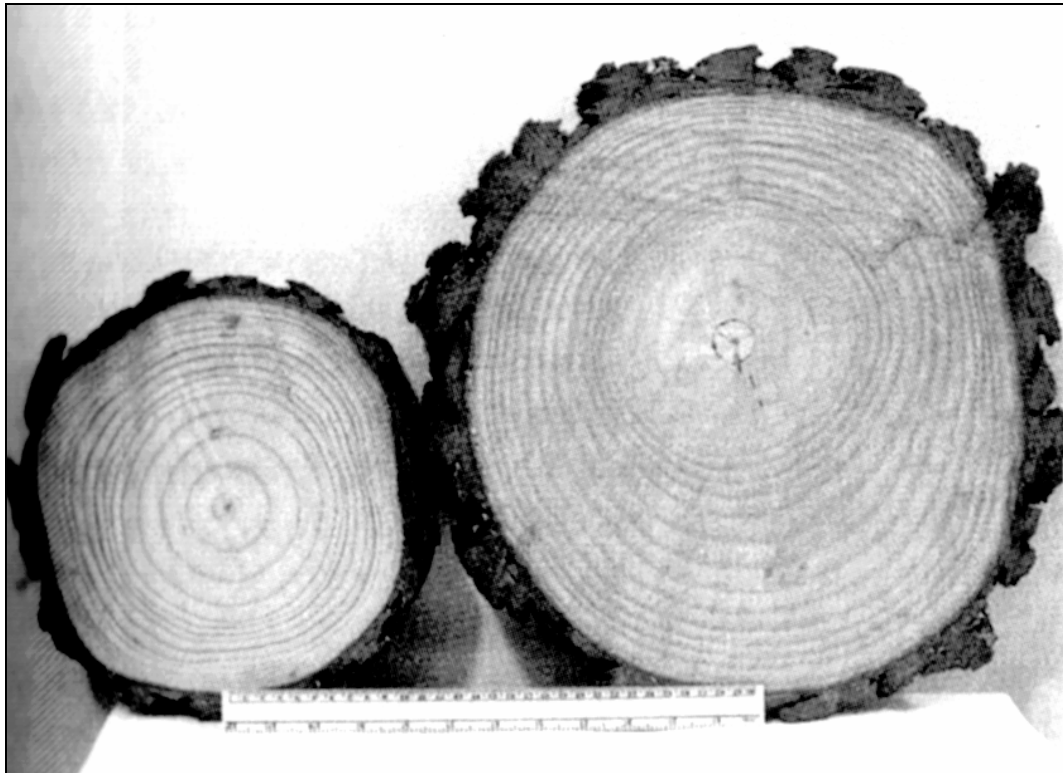
1.3.2 Mensurational Effects

1.3.2.1 Individual Tree Growth

The main effect of thinning is greater diameter growth on the remaining trees. Much research has established that height growth of the trees themselves is usually little affected. NACRMLP has found only little difference in average tree height between thinned and unthinned stands of 25 year old *P patula* and this slight difference may be explained by the removal of smaller trees during thinning operations (refer Annex 2).

This effect of thinning on diameter growth is shown in Figure 1. The kind of response to thinning in Figure 1 is well-established for all species (refer also Annex 2). Thinning, like wider spacing, produces larger individual trees since they have larger crowns producing more wood. Indeed, there is generally a close relationship between crown diameter and stem diameter. Since the response to thinning is mainly in diameter growth with height usually little affected, thinning changes tree shape; overall, the trunk tapers more rapidly.

Figure 1: Growth response of *Pinus patula* to thinning



*Cross-sectional discs from dominant (right) and sub-dominant (left) **Pinus patula** trees growing in a stand that was heavily thinned at 9 years of age. Note increase in ring width 9 – 10 rings from the pith, especially in right-hand disc.)*

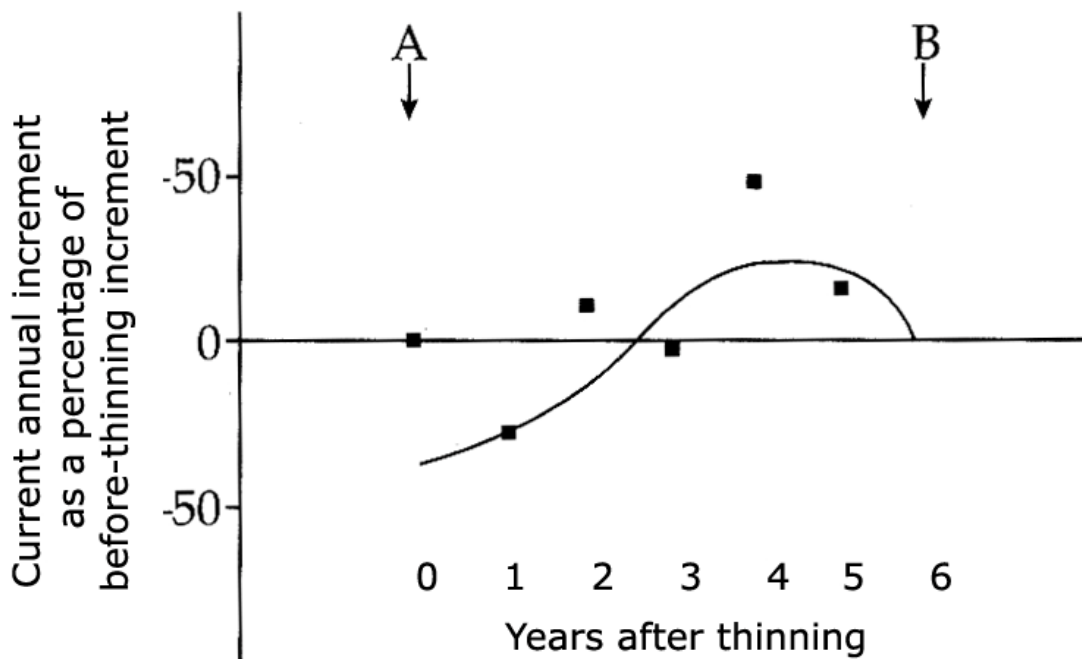
All these effects of thinning only continue while the tree is expanding into the newly available growing space and before between-tree competition again becomes intense. Therefore, if rapid growth of individual trees is sought, thinning is repeated at intervals during the life of a stand.

1.3.2.2 Stand Growth

Removal of trees in thinning immediately reduces some of the photosynthetic surface area in a stand. An immediate drop in production per unit area occurs followed by resurgence in growth as the remaining trees respond to the extra space by increased production of new foliage and roots. It is difficult to demonstrate this recovery of growth because many factors, notably climate, cause year to year variation in stand performance.

Figure 2 is reproduced to show the annual volume increment of a *Pinus patula* stand for 6 years following a heavy thinning carried out at 11.9 years of age. The measured annual increments follow fairly closely the theoretical response curve.

Figure 2: Annual volume increment of a *P Patula* stand following heavy thinning

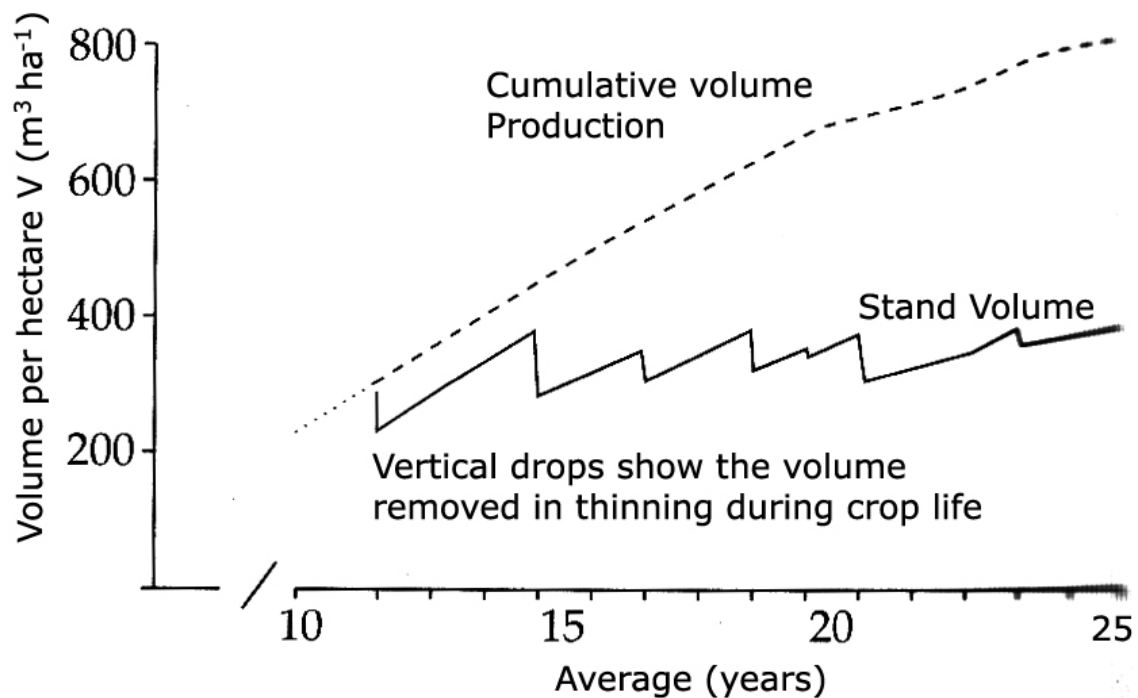


*Increment recovery after thinning. The points are the volume increment recorded after thinning a plot of *P patula* at Peak Timbers, Swaziland. They are shown as a percentage of the plot current annual increment immediately before thinning. At 'A' the plot was 11.9 years old, standing volume was $191.7 \text{ m}^3 \text{ ha}^{-1}$ and $74 \text{ m}^3 \text{ ha}^{-1}$ was removed in thinning. At B the plot was 17.8 years old and standing volume had recovered to $212. \text{ m}^3 \text{ ha}^{-1}$. The solid line shows the theoretical pattern of increment recovery. Source Evans J and Turnbull J (2004).*

Figure 2 shows acceleration in growth, occurring in about the third and fourth year. This improvement is not sustained (except in a stand, which was previously grossly overstocked with many trees dying from acute competition) because thinning itself does not raise site growth potential.

So far the effect of one thinning has been examined, but, as noted, usually several thinnings are carried out. Figure 3 shows the actual development of stand volume, in plots of *Araucaria cunninghamii* thinned regularly to maintain stand basal area at approximately $29 \text{ m}^2 \text{ ha}^{-1}$. Standing volume rises gradually though, of course, the volume is distributed on increasingly fewer trees. Total volume production (volume thinned and volume standing) rises steadily.

Figure 3: Cumulative and standing volume per hectare in a stand of *Araucaria cunninghamii* that was frequently thinned



*Cumulative and standing volume per hectare in a stand of *Araucaria cunninghamii* that was frequently thinned to maintain stand basal area at about 29m²ha⁻¹. Source Evans J and Turnbull J (2004).*

The typical ‘saw-tooth’ pattern of stand volume (Figure 3) shows what thinning does. Immediately there is a drop in stand volume as trees are removed, followed by a steady rebuilding of volume until the next thinning again reduces the volume and the cycle is repeated. This pattern is true of all thinnings, conifers and broadleaves. For most thinning regimes the total volume of timber removed in thinnings during a rotation amounts to about 40-60 % of total production. In Figure 3, by 25.5 years, 52% of the total volume had been cut as thinnings.

To summarize, the effects of thinning are to:

1. Stimulate diameter growth of remaining trees.
2. Redistribute future growth so as to optimise wood production and value among the potentially highest yielding and better formed trees, and reduce natural mortality.

1.3.3 Effects of Different Thinning Intensities

So far only the effects of thinning in general have been considered. However, at any one time thinning can remove many trees or only a few, it can be done lightly or heavily or not at all, and it can vary in intensity.

Intensity in thinning has three related aspects:

1. How early thinning begins - the time of first thinning (considered later).
2. What proportion of the trees are removed in one thinning - thinning weight.
3. How frequently thinning is done - thinning cycle.

Thinning weight (2.) and thinning cycle (3.) are not independent in their relation to intensity. For example, if a regime stipulates that $60 \text{ m}^3 \text{ ha}^{-1}$ (weight) should be thinned every 3 years (cycle) then the annual rate of removal is $20 \text{ m}^3 \text{ ha}^{-1}$. However, this rate of removal (intensity) could also be achieved by felling a greater weight, for example, $100 \text{ m}^3 \text{ ha}^{-1}$ on a longer cycle of five years. In each case the thinning intensity is the same. Provided the thinning cycle is not overly long and the weight of thinning not too heavy, thinning intensity can simply be described in terms of volume removed per hectare per year.

However, removal of a certain volume per hectare per year will not be the same thinning intensity for a slow-growing stand as for a fast one. Thinning 300 m^3 during a 30-year rotation from a stand, which only produced $500 \text{ m}^3 \text{ ha}^{-1}$ in total, represents a more intense thinning than if 300 m^3 had been thinned from one which yielded $650 \text{ m}^3 \text{ ha}^{-1}$. This lack of comparability owing to different growth rates can be overcome by defining intensity as a percentage of the maximum mean annual volume increment a stand will achieve. This approach is used in Britain, but it is not an essential part of thinning practice. For a particular species and site the intensity of thinnings carried out can be considered as the volume of timber removed per hectare per year. In practice basal area per hectare is often used because it is easier to measure.

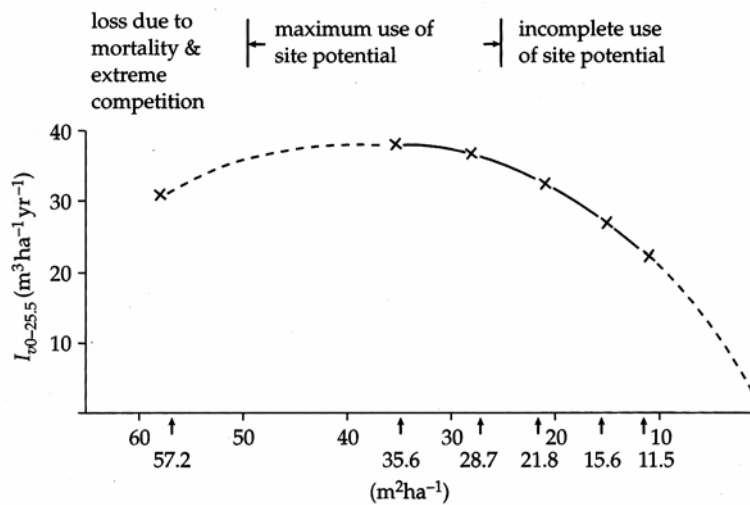
The effects of differing thinning intensities are illustrated below using data from a trial laid down in an 11- year - old *Araucaria cunninghamii* plantation in Papua New Guinea (PNG). When the trial started average stand data were: stocking $1399 \text{ trees ha}^{-1}$; top height 21.3 m; basal area $38.3 \text{ m}^2 \text{ ha}^{-1}$; and average tree volume 0.22 m^3 . Six thinning treatments, replicated four times, were applied. Each treatment involved thinning to a prescribed basal area per hectare and then maintaining this level by further thinning every 2 or 3 years. Five thinning intensities were applied which, over the period of the experiment, held stand basal area (G) at 11.5, 15.6, 21.8, 28.7, and $35.6 \text{ m}^2 \text{ ha}^{-1}$, respectively; the sixth treatment was an un-thinned control. A very heavy thinning was needed to achieve the lowest basal area level of $11.5 \text{ m}^2 \text{ ha}^{-1}$ and 78% of the trees were removed at the first thinning. Other treatments were progressively less severe.

Growth data were analysed 14 years after the trial began when the trees were 25.5 years old. (The progressive development of cumulative and standing volume per hectare shown in Figure 3 is for the thinning treatment where basal area averaged $28.7 \text{ m}^2 \text{ ha}^{-1}$). Figure 4 shows the relationship between thinning intensity and productivity defined as mean annual increment (I_V), that is, standing volume + thinning volume \div age, and Figure 5 shows the relationship with mean tree diameter (dg), and volume (V).

Two conclusions may be drawn from Figures 4 and 5.

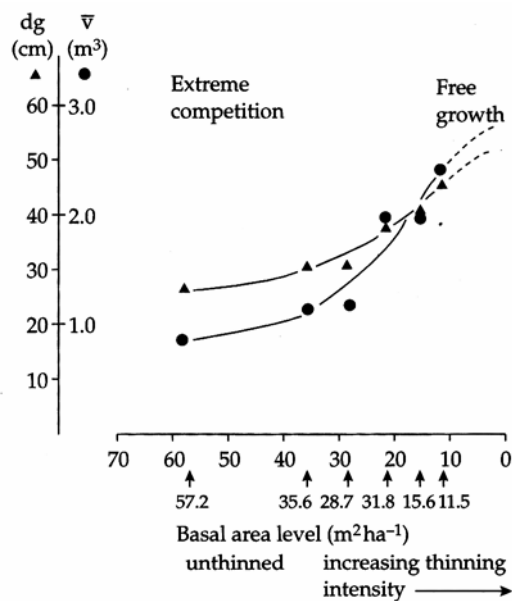
1. Over a moderate range of thinning intensities stand productivity is little affected, but under extreme competition or heavy thinning some loss in production occurs. This observation that stand productivity (increment) is little affected over the range of most 'normal' thinning intensities is commonly reported.
2. Increasing intensity of thinning results in increasingly large individual trees, up to the point of free growth and no between-tree competition.

Figure 4: The relationship between yield (mean annual increment, $I_{0-25.5}$) and intensity of thinning in *Araucaria cunninghamii*.



The relationship between yield (mean annual increment) and intensity of thinning in a plot of *Araucaria cunninghamii*. Source Evans J and Turnbull J (2004).

Figure 5: The relationship between average tree size (mean diameter, d_g ; mean volume, \bar{V}) and intensity of thinning in *Araucaria cunninghamii*.



The relationship between average tree size (mean diameter and mean volume) and intensity of thinning in *Araucaria cunninghamii*. Source Evans J and Turnbull J (2004).

These two general conclusions provide the flexibility thinning offers. The extremes are either to maximize total volume production in a stand, for example, for pulpwood, or that of individual trees, for example, for saw timber. Often both are aimed at and thinning is made as heavily as possible but without causing significant loss in total yield - this would mean thinning to a minimum basal area of around $26 m^2 ha^{-1}$ in Figure 4. This is referred to as thinning at marginal intensity to the limiting basal area, which is the minimum stand basal area that will still yield maximum basal area increment, that is, there is no loss in total yield. Such a thinning has been applied in Queensland, Australia, (Bevege 1967)

though there is now less reliance on commercial thinning to achieve silvicultural objectives (Anderson *et. al.* 1981; Shea 1987).

Effect of constant thinning intensity in practice.

If a constant intensity is applied over a series of thinnings, the actual proportion of volume removed to volume remaining will gradually decline. This accords with the growth response of a stand since the rate of basal area growth declines as trees become larger. Therefore, often in later thinnings, the cycle is lengthened so that thinning weight is increased to make the thinning more worthwhile while still maintaining the same intensity.

1.3.4 Methods of Thinning

Not only can thinning be made at different intensities, but also in different ways. Two thinnings which remove very different kinds of trees can be of the same intensity. Provided volume removed is the same, intensity remains the same, whether many small trees are cut, or just a few, large trees. In fact there are several ways of making a thinning, but two main categories are recognized.

Figure 6: Line thinning in 12-year-old *Pinus patula* in Malawi



1. Systematic, mechanical, or line thinning. Trees are thinned following an objective and systematic procedure in which individual tree quality is not considered. Removal of every third row of trees is an example, (refer Figure 6). In systematic thinning only intensity can be varied.
2. Selective thinning. Trees are thinned or left, depending on the subjective judgment of the person marking the thinning. There are two main methods, and they determine which kinds of trees are removed, low thinning and crown thinning. In selective thinning both intensity and the kind of tree favoured can be varied. Selective thinning is particularly important in species with generally poor form, so that the best stems can be favoured.

1.3.5 Systematic Thinning

In systematic thinning no regard is paid to the canopy class or kind of trees removed. The commonest form is line or row thinning. Thinning weight is altered by varying the proportion of rows removed.

Systematic thinning is not as common in the tropics as in temperate plantations since low labour costs allow the greater time needed in the more subjective and intensive selection systems. Sometimes early thinnings are mechanical or systematic and later ones selective. This is the practice for thinning teak plantations in Nilambur, India; two mechanical thinnings are followed by four selective thinnings over a rotation of 50-55 years (Chundamannii 1998).

1.3.6 Selective Thinning

1.3.6.1 Low Thinning (thinning from below)

This is the commonest form of selective thinning. Low thinning removes mostly trees in the lower canopy classes, that is, the smaller less vigorous trees, plus larger malformed trees, and largely speeds up natural processes. Traditionally, four or five intensities have been recognized, though the exact descriptions differ from country to country. Table 1 gives the classification used in India.

Table 1: Grades of low thinning recognized in India

Grade	Description	Trees removed
A	Light thinning	Dead, moribund diseased, suppressed trees
B	Moderate thinning	Trees in grade A and B, all subdominants, whips, and branchy advance growth which cannot be pruned or lopped.
C	Heavy thinning	Trees in grades A and B, all subdominants, any defective co-dominants and dominants that can be removed without making a permanent gap in the canopy.
D	Very heavy thinning	Trees in above grades and many dominants and co-dominants so that the remaining stand consists only of trees with good boles and crowns, well spaced and evenly distributed over the site.

Source: Based on Champion and Seth (1968).

In all low thinning, because smaller, less vigorous trees are removed, there is an element of selection for vigour. The final crop consists of trees with good form which have always grown faster than average. However, low selective thinning also requires that at each thinning recognition be given to general spacing and competition between trees so that excessive gaps do not occur and trees be thinned unnecessarily without commercial returns.

1.3.6.2 Crown Thinning (thinning from above)

This is more complex than low thinning since crown thinning always involves removal of some dominants and co-dominants to release other trees. Often a number of potential final crop trees are selected and thinning is used to favour their crown development. Crown thinning tends to have two categories of trees, those favoured by the thinning and the rest.

If crown thinning is persisted with throughout a rotation the continual removal of many of the more vigorous trees can lead to some increment loss overall (Johnston et al. 1967). Assman (1970) found that the volume increment contributed by sub-dominants and

suppressed trees in a stand was only 3% and 1%, respectively of the total, and that the increment of these classes per unit area of crown surface is only about half that of dominants. Hence crown thinning, which allows many small trees to be left, even if the total crown surface area is the same as a low thinning, will have smaller growth potential.

Two grades of crown thinning are recognized:

1. Light crown thinning. All dead, dying, and diseased trees are removed along with whips and wolf trees. Also some upper canopy class trees are thinned to break up groups of dominants. Most co-dominants are left.
2. Heavy crown thinning. Final crop trees are usually selected to achieve a certain stocking, for example, 200 trees ha⁻¹, scattered evenly over the site. Heavy thinning is carried out around selected trees to provide almost full crown release (all competing dominants and co-dominants are removed). In early thinning many sub-dominants and some co-dominants are retained as a matrix between these selected final crop trees.

1.3.7 Other Methods of Thinning

Various modifications to the main methods of thinning have arisen of which two are described.

1.3.7.1 Queensland Selection System

This is essentially a systematic method, which includes an element of selection. It has been used in East Africa, PNG, and Queensland, Australia but is now less common. It is applied to teak in PNG in the following way:

1. Before first thinning about 400 good quality trees per hectare are selected.
2. In choosing trees to cut in the first thinning the marker works along each row with the aim of removing three trees out of every group of seven. A form of crown thinning is applied and trees are marked for removal using the following order of priority:
 - a. Diseased or badly deformed trees.
 - b. Poor dominants or co-dominants competing with selected trees.
 - c. Trees with double or multiple leaders.
 - d. Any other trees competing with selected trees.
3. The second thinning removes all remaining trees not selected.
4. The third and fourth thinnings remove poorer selected trees according to low thinning principles.

1.3.7.2 Selection Thinning

This differs from selective thinning and is an extreme crown thinning where dominants are thinned (felled) to favour and release trees of lower canopy class. It is not widely practiced in commercial plantations and is only suitable for shade-bearing species, but is a way of 'creaming' the largest trees from a stand over a number of years. It is not uncommon in small scale pine and Chinese fir plantations in southern China where farmers take advantage of higher prices for larger diameter trees but eventually are left with degraded stands. (Liu 2003). The method can also be a form of corruption. For example, a contractor making a second thinning in a cypress (*C.lusitanica*) stand in East

Africa simply and illegally, though with the connivance of local forestry staff, was observed to take all the biggest and best trees.

A form of 'selection thinning' is common in woodlots managed in social and community forestry as here trees are cut once they reach a certain size. In the Bilate project, Ethiopia, any eucalypt tree can be cut when it has reached a diameter (DBH) of 12 cm: the local community decided on this diameter threshold to supply poles, the commodity in most demand.

1.3.8 Influence of Thinning Method on Stand Development

It was seen earlier that thinning intensity influences both tree and stand development. However, because different thinning methods remove different kinds of trees, thinning method itself also has an immediate effect on a stand. Regardless of intensity, thinning method affects:

1. Mean stand height.
2. Mean diameter and diameter distribution.
3. The ratio of average size of thinned trees to the average size of trees remaining.

In summary, low thinnings increase the average size of the remaining trees because smaller than average trees are mostly removed, while crown thinning has the opposite effect. Systematic thinning is neutral in its immediate effect. So, thinning intensity and method affect subsequent diameter distribution and tree size; the former by redistribution of future increment on varying numbers of trees, the latter by removing smaller, average, or larger than average trees compared with the stand mean.

1.3.9 Thinning and Wood Quality

Thinning, as well as affecting the quantity of usable timber from a stand also affects the quality. Removal of leaning, and misshapen trees, and those with basal sweep or crooked stems, reduces the amount of reaction wood and spiral grain remaining in the stand, and the trees left to grow on will have a higher percentage of utilization. Also, because the remaining trees are encouraged to grow to large size their sawlog and veneering potential is improved since less of the log is wasted.

Thinning may also have some negative effects:

1. Increase in taper. This may reduce slightly the percentage utilization of the log. Adlard and Richardson (1979) report this effect with *P. patula* in Tanzania. However, without thinning overall merchantable log length is decreased because of decreased log diameters.
2. Potential increase in coarseness of branches and knot size. For this reason high pruning is often done in conjunction with thinning.
3. More rapid diameter growth. This may lead to slightly less dense wood, slightly shorter fibre length, and the amount of juvenile wood may increase. Dominants in a stand tend to have lower wood specific gravity, and therefore slightly lower strength characteristics than other canopy classes, and over dominants a forester has least control. The important aim in growing timber is evenness in growth; this is produced

by regular, moderate thinnings. Infrequent, very heavy thinnings lead to greater variation in wood properties.

4. Damage to the stand and soil. Extraction of thinnings may snap branches and rub bark off remaining trees increasing the risk of infection by pests or disease, including wood decaying fungi. Also, along extraction tracks soil may be compacted and root damage may occur.

1.4 Thinning Decisions

Whether to thin at all is the first of several questions to be decided. But, if thinning is intended, three decisions must be taken:

1. When to thin?
2. What intensity to apply?
3. Which method to use?

1.4.1 Management Objectives and Thinning Policy

The reasons for thinning were listed at the beginning of the chapter. But it is the purpose of growing trees which lies behind these reasons and which is the main consideration in what thinning policy to apply.

Broadly, there are five main uses for plantation wood. In order of increasing desirable log size these are: firewood; building poles; pulpwood, and reconstituted board products; sawn timber, low and high grade; and veneer, peeling for plywood and slicing for decorative quality. After species choice, which determines the kind of wood produced and rate of growth, the thinning regime and length of rotation are the main determinants of log size. In plantation management clear end-use objectives are usually specified, and thinning at the right time, in the right way, and at the right intensity is an important tool to achieve them.

In woodlots and small plantations managed in farm forestry and social forestry, formal thinning primarily for the improvement of the remaining stand is usually not done because the objectives are supply of a variety of products. Firewood may be regularly gathered by cutting small trees while larger trees are left to grow to pole size. Thinning to obtain the firewood may be as, or more, important than influencing future stand development.

1.4.2 The No-thinning Option

Thinning is a costly exercise and so it needs to be balanced with the benefits that would accrue, both from the sale of thinnings and longer term improved wood value returns as well as against the risks of not thinning. Where labour costs are high there is an increasing tendency to avoid thinning if possible bearing in mind that there is usually no loss of total wood volume production by not thinning, provided extreme competition does not cause significant mortality, and this can be avoided by keeping rotations short or by sufficiently wide initial spacing. However, even without direct mortality, there is evidence, especially in the case of pines, that unthinned densely stocked stands can increase the risk of insect attack. Lack of thinning precipitates *Sirtex* wood-wasp attack of pines, including *P. patula* and *P. elliotii*, when trees are under stress, such as from severe competition (Kirsten *et al.* 2000). This effect has also been reported for bark beetle

infestation in stands of *P. caribaea* and *P. oocarpa* in Honduras (Reyes and Groothousen 1990). Control is affected by thinning before stands reach 15 years of age and removing about 40% of basal area.

Where maximum wood or fibre production is the objective and quality is not so important, thinning may not be needed. It is rarely carried out in plantations grown for pulpwood, fuel-wood, or rough poles in which high yield, moderate tree size, and short rotations are desirable. Most of the extensive *Acacia mangium* plantations grown for pulpwood in Asia are not thinned (Srivastava 1993) but sawlog prescriptions for this species developed in Peninsular Malaysia recommend thinning (combined with high pruning) to maximize diameter growth over a 15-year rotation (Mead and Speechly 1991).

In plantations established primarily to protect the soil and prevent erosion, often no thinning is done or it is very light to avoid damage to the site from logging and to prevent large breaks in the canopy. However, in such protection stands, gradual thinning over a long rotation may encourage natural regeneration. The no-thinning option may also be chosen in plantations considered susceptible to wind damage, since the operation of thinning may render trees more susceptible to both wind-throw and stem-break. However, on long rotations the reverse may hold: Adlard (1980) reported most damage in densely stocked stands of *P patula* in Tanzania.

With a policy of no thinning, low pruning is usually limited to some parts of the crop to reduce the fire hazard. It is cheaper to remove branches from the bottom 2 m of a tree after it is cut down than to low prune it while standing.

1.4.3 Timing of First and Subsequent Thinnings

The first thinning has been described as the most important management and silvicultural operation in a rotation because it largely defines the course and flexibility of subsequent operations and the log size assortments it will be possible to produce (Lewis *et al.* 1976).

Wadsworth (1997) similarly stresses its importance for many kinds of tropical plantations. First thinning is also the occasion when vigorous, coarsely branched or multiple-leader trees must be removed (de-wolfing) before they dominate too much and irreparably harm stand quality: this is particularly important in stands of *Pinus kesiya* and other species exhibiting only moderate form. Silviculturally, the timing of any thinning is best judged by examining the live crown ratio. Thinning should be undertaken before a crown becomes too small; for many broadleaved species before the live crown ratio is reduced to 30 - 40%, and for pines about 40 - 50%. Other approaches adopt basal area as the indicator and Mayhew and Newton (1998) report 22-24 m² ha⁻¹ as the minimum basal area level to aim at for mahogany stands and hence one way of deciding when thinning should start. However, with all thinnings, economic considerations tend to cause deferment until trees are larger and costs per cubic metre of harvesting timber are lower. This tendency can impair subsequent stand development as well as enhance the risk of pest attack as noted above, and the suppression of many trees in a stand just as Perera (1988) reported for unthinned *P caribaea* and *P. patula* in Sri Lanka.

Where early thinnings may be unsaleable, re-spacing some time before canopy closure may be advantageous. However, sometimes thinning is carried out at the optimum time to maintain stand growth but the timber is not extracted. This is called a pre-commercial thinning or thinning to waste and, along with reduced initial stocking, is becoming the preferred management in Queensland conifer plantations, with less reliance on commercial thinning to achieve silvicultural objectives (Shea 1987). The number of thinnings has been reduced from seven to only three during the rotation. For *P caribaea* in Queensland, Shea *et al.* (1984) showed that one heavy pre-commercial thinning, of a widely spaced (5 by 4.4 metre) crop, reducing stocking to 300 stems ha⁻¹ was more attractive economically than carrying out conventional thinnings of more closely spaced crops.

First thinning in tropical plantations is often done 2-4 years after canopy closure. In general faster growth brings forward the time of first thinning and the need to repeat thinnings while wider initial spacing and heavier thinning have the opposite effect. The exact timing of thinning is often laid down by prescription.

1.4.4 Thinning Intensity

If it is essential to achieve maximum yield from a stand then thinning must be at or less than marginal intensity (limiting basal area) and tree size becomes primarily determined by rotation length. However, in some situations it is worthwhile to thin more heavily than marginal intensity, despite some loss in total volume production. In particular if large logs command a high price, for example, for veneer the good increment on relatively few well-spaced trees may be more valuable than the volume shortfall. Where heavy thinning is carried out for this purpose the term 'value increment' is sometimes used for the enhanced growth of the selected trees.

In most plantations thinning is done at or near marginal intensity though it may not be recognized as such. However, because thinning is costly, and the out-turn often only covers the cost of the operation, it is important to ensure it is done efficiently. One way is to thin heavily at infrequent intervals. It is cheaper to thin 60 m³ ha⁻¹ from a stand every 5 years than to thin just 12 m³ ha⁻¹ every year, though both regimes are the same intensity. Provided a stand is dynamic and can respond to occasional heavy thinnings as well as light ones, the thinning cycle may be varied within limits, to suit the local market or other economic considerations. In such situations the only thinning decision is to stipulate intensity.

1.4.5 Choice of Thinning Method

1.4.5.1 Systematic Thinning

In terms of cost per cubic metre systematic methods are the cheapest form of thinning as:

1. Little specialist knowledge is required.
2. The need for supervision is small.
3. Trees do not need marking before thinning.
4. Felling and extraction of felled trees is easier.

The main disadvantage of systematic thinning is that the condition and quality of the trees felled or left are ignored, which is more of a problem when the genetic quality of the planting material is highly variable. Deformed and diseased trees in unthinned rows are left while good phenotypes may be lost in felled rows. Another disadvantage, especially of line thinning, is increased susceptibility of the stand to windthrow owing to one sided exposure of a tree's crown and discontinuity of root systems.

Systematic thinning is most suited to first, or first and second thinnings as an inexpensive way to reduce stocking and increase growing space per tree. In later thinnings, the method is less suitable because the original orderliness of the stand has disappeared and most of the advantages which make it cheaper no longer apply. However, as a method of early thinning, the ease of application in and cheapness of systematic methods are leading to their increasing use.

1.4.5.2 Selective Low Thinning

This is the most costly method in the short term because it involves removing many small trees. Marking trees for thinning is not difficult since it is usually easy to decide which are the poorest. Also, because mostly smaller trees are felled, difficulties with take-down are not great.

Low thinning removes the smaller, less vigorous trees in a stand, thus future increment is concentrated on the best, faster growing ones of good form, that is, low thinning has an element of positive selection. Comparisons between line thinning and selective low thinning with *P. patula* in Colombia (Ladrach 1980) and *P. caribaea* in Queensland (Queensland Department of Forestry 1985) have shown precisely this small but positive growth advantage selective thinning gives to stand increment. In financial terms low thinning is an investment into future capital. For this reason low thinnings tend to realize the highest site growth potential and, in the long term, are the most profitable.

1.4.5.3 Crown Thinning

Crown thinning has two important advantages. First, a few selected trees are favoured and their growth encouraged. Second, by felling larger trees in earlier thinnings there is initially a better financial return and the cost of thinning per cubic metre is generally less, though take-down can be difficult. The most difficult part of crown thinning is in marking. No two people will wholly agree on which trees to fell and which to leave, and marking can become very time-consuming.

The effects of crown thinning on productivity were noted previously. In practice, stands are often given crown thinning initially and low thinning later in the rotation. Crown thinning and heavy low thinning are the most commonly practised methods in tropical plantations.

1.5 Thinning Practice and Control

With systematic thinning, control is no problem, intensity is defined by removal of every third, fourth row, etc., and it is clear which trees are to be felled. In selective thinning the trees to be felled (or left) must be marked in advance. Control of thinning in this case has to ensure that both the right kinds of trees and in the right quantity are felled. This requires trained markers; instruction in the kinds of trees to remove is fairly straightforward, but controlling the intensity of thinning uniformly over a stand can be difficult. In the tropics two control systems are widely used, one based on basal area, the other on number of trees.

1.5.1 Basal Area Control

In this system the object is to thin to a certain after-thinning basal area. This is achieved by estimating the before-thinning basal area, marking the trees to be thinned, and then estimating the after-thinning basal area. The method is slow if individual tree diameters are measured, but this is not necessary if a relascope is used to estimate stand basal area. In practice, basal areas are checked by establishing temporary plots as the stand is being marked. Tables are often available which indicate the basal area to be removed in a crop of a particular species, age, and site quality. Hussain and Cheema (1987) recommend the basal area control method for *Eucalyptus camaldulensis*., Seitz (1990) quotes percentage of basal area to remove each thinning in *P. caribaea* stands to prevent bark beetle attack, and the examples cited by Mayhew and Newton (1998) for mahogany were noted above.

1.5.2 Stem Number Control

This method is simpler and more common than basal area control; thinning follows prescribed stocking levels for a stand of a particular species, age, and growth rate. The number of trees to be thinned per hectare at each thinning is stipulated. This system is the most widely used, particularly in Africa. For example, it is the method laid down for all plantation species in Kenya (pines, cypress, juniper, *Vita* and *Bischofia*) in the country's technical orders (Mayhew and Newton 1998). Table 2 illustrates one example in use in Queensland in the 1990s.

Table 2: Thinning prescriptions for *Pinus caribaea* var. *hondurensis* for sawlog in Queensland, Australia

Thinning number	Age (years)	Stocking before thinning (no. ha ⁻¹)	Stocking after thinning (no ha ⁻¹)	Thinning method
Planting	0	746	700	94% survival
1	2-3	700	500	Pre-commercial
2	22	500	300	Selective
	30	300		clear fell

Note: Variations in these prescriptions exist throughout Queensland depending on local demand for thinnings, distance to markets, growth rates, and accessibility to stands etc. The prescription shows for *P. caribaea* applies to stands in tropical Queensland (north of 23°S)

1.5.3 Thinning and Regeneration

Thinning, especially later thinnings and the opening of gaps in the stand, often promotes natural regeneration of tree species; both from the existing plantation and of local indigenous species. Such regeneration may or may not be wanted, since at final felling the opportunity may be taken to introduce a new species or use superior planting stock.

However, this phenomenon has recently come to the fore with the potential of rehabilitation within the two project districts. There the pine plantations have reintroduced forest conditions after past clearance of the land, and thinning can encourage natural regeneration of native species. NACRMLP has found that young regeneration of *P. patula* is profuse in 25 year old plantations of that species where there has been fire in the past and the canopy has been opened. In some thinned area, regeneration of broad leaf species like *Schima wallichii* (Chilaune), *Fraxinus floribunda* (Lankuri), *Lyonia villosa* (Angeri) is also found.

As early plantations near their clear fell age, it will be necessary for Community Forest User Groups (CFUG) to consider their options for restocking; whether to take advantage of natural broadleaf or pine regeneration, or to introduce new and possibly better performing species or varieties.

1.6 Potential Risks Associated with Thinning

In specific circumstances, thinning involves risks. Most significant is the risk of windbreak and wind-throw amongst remaining trees after the crop canopy has been opened up during thinning. This risk of wind-throw and wind-break is significant after heavy thinning on exposed ridge top sites where thinning has previously been delayed and the trees are unduly weak due to restricted root and stem diameter growth.

1.7 Economic Considerations in Thinning

Thinning is a medium term investment in protecting a valuable asset (the forest) and enhancing its value. In most cases it is a profit making activity in which income from sale of produce exceeds expenditure. In some cases however, early thinnings are undertaken at a loss in order to enhance the value of the remaining crop. In NACRMLP districts demand is fortunately high though, and it seems that even early thinnings should return a profit.

Economic considerations also have bearing on the type of thinning to be applied. Where labour costs are high, mechanical line thinnings are often adopted; whilst in countries like Nepal where labour is available and relatively inexpensive, selection systems are more appropriate.

2 Status of Plantations and Effect of Previous Management

Most of the pine plantations in Kabhre Palanchok and Sindhu Palchok Districts were established by the Afforestation Division of Department of Forest in the beginning and later on by District Forest Offices (DFO) of Kabhre Palanchok and Sindhu Palchok from 1978 to 1991 with Australian Government grants. In the beginning, emphasis was given to planting pine because these species are less susceptible to grazing and can readily be established at low cost in degraded areas with poor soils.

Most of these pine plantations are now managed by Community Forest User Groups according to Operation Plans which are approved by District Forest Officers. Until recently the emphasis has been on establishing and managing forest plantations to protect watersheds and provide for subsistence needs. Thus most plantations have not been actively managed for wood production and are overstocked and lack stand treatment. The trees are often stressed and subject to insect attack. The plantations are currently not in a state to effectively meet the needs of the communities that have invested in their development and protection.

In many areas where the pine forest canopy has been opened up native broad leaf species and pine have started to become established through natural regeneration.

There is a ready sellers' market for all dimensions of pine thinnings in the Kathmandu valley and elsewhere, but in the limited instances in which thinnings have been sold the benefits have tended to be captured by local elites and not distributed in an equitable manner. Women and the disadvantaged have not benefited fairly from early commercial activities and are understandably skeptical. Women who are responsible for collecting animal fodder much prefer palatable broadleaf species to the unpalatable pine which provides them with scant benefits.

The pine forests are, however, a valuable if underutilized and under managed asset, and with minimal interventions, which can be applied during the agricultural off season, they can yield substantial early returns, generate employment opportunities and at the same time be developed into more productive assets. Measurement of growth responses to the limited thinning interventions that have been tried in the past demonstrate conclusively that local plantations do respond well to thinning (refer Annex 2).

3 Thinning Guidelines

3.1 Forest Plantation End-use Objectives

The community forest user group members are amongst the most poor and vulnerable people. Their precarious livelihoods are centred on upland farming. They cannot afford artificial inputs and so are dependent on animal manure and therefore fodder collection from near their scattered farms. They are beset by local conflict over resource use and traumatised by the civil conflict going on around them.

Poverty and massive inequity are at the heart of these conflicts and so livelihood and equity related improvements are essential.

The forest plantations are a major resource and there is conflict over their management. Some, mostly women, wish to see a shift of emphasis from pine forestry towards the growing of more palatable species, whilst men, on the other hand, are interested in the employment and cash generation opportunities of pine plantation management. None have experience of the full potential benefits of scientific plantation management.

National priorities for poverty reduction, conflict reduction, watershed protection and industrial development are also of relevance.

Forest plantation management cannot be used to address social equity issues. Parallel coordinated interventions are required here but Community Forest User Groups do provide suitable entry points for equity related interventions. Forest plantation management can however be used to generate resources and finance broad based equitable livelihood improvements.

The current default position of no active management is not benefiting anybody. Over the next few years therefore the purpose has to be to introduce management which will:

1. Deliver benefits that are relevant to all stakeholders.
2. Give good returns on investment.
3. Not jeopardize the aspirations of any group.

Given the current state of the plantations and the ready market for all dimensions of logs, it is appropriate to start managing the plantations to produce large dimension sawlogs. The necessary thinning operations will produce early returns and apart from increasing the growth and value¹ of the final crop trees will lead to broad leaved natural regeneration and fodder production.

¹ Pashupati furniture in Kathmandu offer Nepalese Rupees (NR) 120/cubic foot for *P Patula* logs between 4" and 8" diameter, NRs 140 / cubic foot for logs between 8" and 12" diameter and NRs 160 per cubic foot for logs over 12" mid diameter (pers comm. Pashupati Furniture, Kathmandu, 2005)

3.2 When to Thin?

Thinning is mostly a dry winter season activity because labour is available, the forests are accessible and pine logs degradation prior to utilization is minimised.

As noted previously, the first thinning has been described as the most important management and silvicultural operation in a rotation because it largely defines the course and flexibility of subsequent operations and the log size assortments it will be possible to produce.

Almost all the plantations have been damaged by previous lack of attention to thinning and it is not possible to reverse this damage. Younger plantations are however best able to respond to thinning operations and so attention should first be given to regularising their stocking levels before attending to the older plantations.

3.3 What Intensity to Apply?

In overstocked stands reducing stocking to that normally prescribed for the age class in well managed stands is not feasible as the overstocking will have stunted tree canopy and root development, and consequently reduced their ability to respond rapidly to being provided with more space to grow. A phased approach is necessary in regularising stocking whilst at the same time maintaining optimum site productivity. The phased approach will also provide the communities associated with the plantations the opportunity to maintain as continuous an income as possible over the short to medium term.

3.4 Thinning Prescriptions

Thinning prescriptions for overstocked plantations are organised and set out in tabular form as below:

- Table 3: Thinning Guidelines for *Pinus patula* planted between 1986 and 1990.
- Table 4: Thinning Guidelines for *Pinus patula* planted between 1980 and 1985.
- Table 5: Thinning Guidelines for *Pinus roxburghii* planted between 1986 and 1990.
- Table 6: Thinning Guidelines for *Pinus roxburghii* planted between 1980 and 1985.

Thinning prescriptions for younger plantations and more ideally stocked plantations are presented in Annex 1.

Principles behind the thinning prescriptions

Bearing in mind the foregoing thinning concepts, the condition of the pine plantations in the two project districts and the requirements of the local communities, the following principles are considered in relation to thinning the pine plantations:

- Assume that all stands are being ultimately managed for sawlog production with other products, such as fuelwood, secondary.
- In overstocked stands reducing stocking to that normally prescribed for the age class in well managed stands is not feasible as the overstocking will have reduced tree growth potential as well as tree diameters and resultant basal areas, so that a phased

approach is necessary to achieve normal stocking bearing in mind the need to maintain optimum site productivity.

- The need to even out wood production from plantations so as to ensure a more even flow of revenue to the community. Thus, although a more drastic thinning may be called for particularly at an early stage, the trees actually thinned may be reduced and a further thinning carried out after a short period.
- Endeavouring to maintain adequate stocking to not lose productivity on the site. Basal area is used as a measure to maintain productivity, endeavouring to keep it above 20 m² ha⁻¹. However, this is not always possible in the later stages of thinning, but at that point full site occupancy is not such an issue.
- Considering the requirements to support the regeneration of suitable broadleaved species, which the community may prefer as a future forest crop on the same land.

Age Classes

The thinning prescriptions are based on two age categories for both *P. patula* and *P. roxburghii*: **15 to 19 years** and **20 to 25 years**. These cover the major age classes for the plantations. The final rotation for *P. patula* is prescribed as 45 years, though it may be as young as 40 years for faster growing stands, and as old as 50 years for slower growing stands. For *P. roxburghii* the rotation age is taken as 55 years, though again there may be a margin of five years either way depending on the quality of the stand and the growth rate.

Hunt, Dangal and Shrestha (2001) prescribe a rotation of 40 years for *P. patula* and 50 years for *P. roxburghii* for sawlog production, while rotations of 30 to 36 years have been used for *P. patula* in Kenya, Zimbabwe and South Africa. However, given the poor management record and lack of thinning of the pine plantations in the two project districts and the slower growth rates than in Eastern and Southern Africa, a slightly longer rotation is appropriate here.

Stocking

As the initial spacing at planting 2.5 x 2.5m, or 1,600 plants per hectare, three existing stocking scenarios have been chosen for the guidelines, assuming varying degrees of thinning and/or mortality:

- **1,300 to 1,500** stems per hectare (no thinning).
- **1,100 to 1,300** stems per hectare (higher mortality or maybe one thinning).
- **800 to 1,100** stems per hectare (some thinning and/or heavy mortality).

The final stocking varies from 160 to 240 trees per hectare. Although a final stocking of 150 trees per hectare is prescribed by Hunt et al (refer Annex 1), higher stockings are prescribed here because further thinnings would reduce the basal area to well below 20 m²ha⁻¹ for the final felling, negating the utility of such thinnings. The higher final stockings are for unthinned stands, particularly in older stands and for *P. roxburghii*.

3.5 Which Method to Use?

The low thinning variety of selective thinning will be applied (refer para. 1.3.6.1) during which dead, dying, diseased, poorly formed and suppressed trees will be removed in such a manner as to leave evenly distributed, well formed vigorous trees to develop into the final crop with consideration for root and crown competition.

In practice existing plantations are clumpy in nature with dense patches and relatively open patches. The aim will be to thin so that even the dense patches are reduced to the specified stocking density irrespective of whether they are surrounded by poorly stocked areas. It is anticipated therefore that overall remaining stocking after thinning will often be less than prescribed ideal stocking.

Table 3: Thinning Guidelines for *Pinus patula* planted between 1986 and 1990

Current Age	Stocking	Thin to	Percent Thinned	Av. Spacing Before Thin	Av. Spacing After Thin	Av. Trees Thinned	Av dbh Current Incr	Average dbh	Av B.A.Before Thin	Av. B.A.After Thin	Av Volume Thinned
(years)	(Stems/ha)	(Stems/ha)		(m)	(m)	(Nos)	(cm)	(cm)	(sqm/ha)	(sqm/ha)	(cum/ha)
15 - 19	1,300 - 1,500	1,050	25	3 x 2.5	3 x 3	350	0.4	22.0	53	40	73
plus 3 (av 20)	1,050	750	29	3 x 3	4 x 3.5	300	0.5	23.5	46	33	75
Plus 4 (av 24)	750	550	27	4 x 3.5	4.5 x 4	200	0.6	26.0	40	29	64
plus 4 (av 28)	550	400	27	4.5 x 4	5 x 5	150	0.6	28.4	35	25	59
plus 5 (av 33)	400	280	30	5 x 5	6 x 6	120	0.6	31.4	31	22	58
plus 5 (av 38)	280	180	36	6 x 6	8 x 7	100	0.5	34.0	25	16	57
45	180	0	100	8 x 7		180	0.4	37.0	19	0	135
15 - 19	1,100 - 1,300	850	29	3 x 3	3 x 4	350	0.6	24.0	54	38	91
plus 3 (av 20)	850	600	29	3 x 4	4 x 4	250	0.6	25.8	44	31	78
plus 4 (av 24)	600	450	25	4 x 4	4.5 x 5	150	0.7	28.6	39	29	60
plus 4 (av 28)	450	300	33	4.5 x 5	6 x 6	150	0.7	31.4	35	23	73
plus 4 (av 32)	300	200	33	6 x 6	7 x 7	100	0.6	33.8	27	18	58
45	200	0	100	7 x 7		200	0.4	39.0	24	0	167
15 - 19	800 -1,100	700	26	3 x 3	3.5 x 4	250	0.7	26.0	50	37	80
plus 3 (av 20)	700	500	29	3.5 x 4	4.5 x 4	200	0.7	28.0	43	31	77
plus 4 (av 24)	500	350	30	4.5 x 4	5 x 5	150	0.8	31.2	38	27	72
plus 4 (av 28)	350	260	26	5 x 5	6.5 x 6	90	0.7	34.0	32	24	53
plus 5 (av 33)	260	180	31	6.5 x 6	8 x 7	80	0.6	37.0	28	19	58
45	180	0	100	8 x 7		180	0.4	42.0	25	0	181

Table 4: Thinning Guidelines for *Pinus patula* planted between 1980 and 1985

Current Age	Stocking	Thin to	Percent Thinned	Av. Spacing Before Thin	Av. Spacing After Thin	Av. Trees Thinned	Av dbh Current Incr	Average dbh	Av B.A.Before Thin	Av. B.A.After Thin	Av Volume Thinned
(years)	(Stems/ha)	(Stems/ha)		(m)	(m)	(Nos)	(cm)	(cm)	(sqm/ha)	(sqm/ha)	(cum/ha)
20 - 25	1,300 - 1,500	1000	29	3 x 2.5	3 x 3	400	0.3	23.5	61	43	104
plus 3 (av 26)	1000	700	30	3 x 3	3.5 x 4	300	0.4	24.8	48	34	91
plus 4 (av 30)	700	500	29	3.5 x 4	4.5 x 5	200	0.6	27.2	41	29	76
plus 4 (av 34)	500	350	30	4.5 x 5	5 x 5	150	0.5	29.2	33	23	68
plus 5 (av 39)	350	180	49	5 x 5	8 x 7	170	0.5	31.6	27	14	93
45	180	0	100	8 x 7		180	0.4	34.0	16	0	118
20 - 25	1,100 - 1,300	850	29	3 x 3	3 x 4	350	0.5	25.0	59	42	103
plus 3 (av 26)	850	600	29	3 x 4	4.5 x 4	250	0.5	26.5	47	33	86
plus 4 (av 30)	600	400	33	4.5 x 4	5 x 5	200	0.7	29.4	41	27	88
plus 4 (av 34)	400	260	35	5 x 5	6.5 x 6	140	0.6	31.8	32	21	75
plus 5 (av 39)	260	160	38	6.5 x 6	8 x 7	100	0.5	34.4	24	15	65
45	160	0	100	8 x 7		160	0.4	37.0	17	0	125
20 - 25	800 - 1,100	650	32	3 x 3	4 x 4	300	0.7	27.0	54	37	107
plus 3 (av 26)	650	450	31	3 x 3	5 x 4.5	200	0.7	29.0	43	30	86
plus 4 (av 30)	450	300	33	5 x 4.5	6 x 6	150	0.8	32.2	37	24	82
plus 4 (av 34)	300	220	27	6 x 6	7 x 7	80	0.6	34.6	28	21	53
plus 5 (av 39)	220	150	32	7 x 7	8 x 8	70	0.5	37.0	24	16	55
45	150	0	100	8 x 8		150	0.4	39.5	18	0	138

Table 5: Thinning Guidelines for *Pinus roxburghii* planted between 1986 and 1990

Current Age	Stocking	Thin to	Percent Thinned	Av. Spacing Before Thin	Av. Spacing After Thin	Av. Trees Thinned	Av dbh Current Incr	Average dbh	Av B.A.Befor e Thin	Av. B.A.After Thin	Av Volume Thinned
(years)	(Stems/ha)	(Stems/ha)		(m)	(m)	(Nos)	(cm)	(cm)	(sqm/ha)	(sqm/ha)	(cum/ha)
15 - 19	1,300 - 1,500	1,050	25	3 x 2.5	3 x 3	350	0.4	17.0	32	24	32
plus 4 (av 21)	1,050	850	19	3 x 3	3 x 4	200	0.5	19.0	30	24	26
Plus 4 (av 25)	850	650	24	3 x 4	4 x 4	200	0.6	22.0	32	25	36
plus 5 (av 30)	650	500	23	4 x 4	5 x 4	150	0.4	24.0	29	23	34
plus 6 (av 36)	500	380	24	4.5 x 4	5 x 5	120	0.4	26.4	27	21	34
plus 6 (av 42)	380	280	26	5 x 5	6 x 6	100	0.3	28.2	24	17	34
plus 6 (av 48)	280	200	29	6 x 6	7 x 7	80	0.3	30.0	20	14	33
55	200	0	100	7 x 7		200	0.2	31.5	16	0	94
15 - 19	1,100 - 1,300	900	25	3 x 3	3 x 4	300	0.5	18.0	31	23	34
plus 4 (av 21)	900	700	22	3 x 4	4 x 3.5	200	0.6	20.4	29	23	31
Plus 4 (av 25)	700	550	21	4 x 3.5	4.5 x 4	150	0.6	23.4	30	24	32
plus 5 (av 30)	550	450	18	4.5 x 4	5 x 4.5	100	0.5	26.0	29	24	28
plus 6 (av 36)	450	350	22	5 x 4.5	5 x 5	100	0.4	28.4	29	22	35
plus 6 (av 42)	350	250	29	5 x 5	6.5 x 6	100	0.3	30.2	25	18	41
plus 6 (av 48)	250	180	28	6.5 x 6	8 x 7	70	0.3	32.0	20	14	34
55	180		100	8 x 7		180	0.2	33.5	16	0	99
15 - 19	800 - 1,100	750	21	3 x 3	3.5 x 4	200	0.6	19.0	27	21	28
plus 4 (av 21)	750	600	20	3.5 x 4	4 x 4	150	0.7	21.8	28	22	29
Plus 4 (av 25)	600	500	17	4 x 4	5 x 4	100	0.6	24.8	29	24	27
plus 5 (av 30)	500	420	16	5 x 4	5 x 5	80	0.5	27.4	29	25	27
plus 6 (av 36)	420	320	24	5 x 5	5 x 6	100	0.4	29.8	29	22	42
plus 6 (av 42)	320	240	25	5 x 6	7 x 6	80	0.3	31.6	25	19	39
plus 6 (av 48)	240	180	25	7 x 6	8 x 7	60	0.3	33.4	21	16	34
55	180			8 x 7		180	0.2	35.0	17	0	117

Table 6: Thinning Guidelines for *Pinus roxburghii* planted between 1980 and 1985

Current Age	Stocking	Thin to	Percent Thinned	Av. Spacing Before Thin	Av. Spacing After Thin	Av. Trees Thinned	Av dbh Current Incr	Average dbh	Av B.A.Before Thin	Av. B.A.After Thin	Av Volume Thinned
(years)	(Stems/ha)	(Stems/ha)		(m)	(m)	(Nos)	(cm)	(cm)	(sqm/ha)	(sqm/ha)	(cum/ha)
20 - 25	1,300 - 1,500	1000	29	3 x 2.5	3 x 3	400	0.2	19.0	40	28	54
plus 5 (av 28)	1000	750	25	3 x 3	3.5 x 4	250	0.4	21.0	35	26	43
plus 6 (av 34)	750	550	27	3.5 x 4	4.5 x 4	200	0.4	23.4	32	24	45
plus 7 (av 41)	550	400	27	4.5 x 4	5 x 5	150	0.3	25.2	27	20	41
plus 7 (av 48)	400	240	40	5 x 5	7 x 6	160	0.3	27.0	23	14	53
55	240	0	100	7 x 6		240	0.2	28.5	15	0	92
20 - 25	1,100 - 1,300	850	29	3 x 3	3.5 x 3.5	350	0.4	20.0	38	27	55
plus 5 (av 28)	850	600	29	3.5 x 3.5	4 x 4	250	0.6	23.0	35	25	55
plus 6 (av 34)	600	400	33	4 x 4	5 x 5	200	0.5	26.0	32	21	58
plus 7 (av 41)	400	280	30	5 x 5	6 x 6	120	0.3	27.8	24	17	42
plus 7 (av 48)	280	200	29	6 x 6	7 x 7	80	0.3	29.6	19	14	33
55	200	0	100	7 x 7		200	0.2	31.0	15	0	94
20 - 25	800 - 1,100	650	32	3 x 3	4 x 4	300	0.5	21.0	33	23	68
plus 5 (av 28)	650	450	31	4 x 4	5 x 4.5	200	0.6	24.0	29	20	59
plus 6 (av 34)	450	300	33	5 x 4.5	6 x 6	150	0.5	27.0	26	17	58
plus 7 (av 41)	300	240	20	6 x 6	7 x 7	60	0.3	28.8	20	16	26
plus 7 (av 48)	240	180	25	7 x 7	8 x 8	60	0.3	30.6	18	13	31
55	180	0	100	8 x 8		180	0.2	32.0	14	0	105

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Annex 1

Thinning Tables for Young *P patula* and *P roxburghii* and Normally Stocked Established Stands

Annex 1: Thinning Tables for Young *P. patula* and *P. roxburghii* and Normally Stocked Established Stands

The tables below which are extracted from Hunt *et. al.*. (2001) are suitable for young and second rotation crops and also for more ideally stocked established stands.

Areas of young natural regeneration should be re-spaced by cutting out surplus regeneration in order to bring stocking in line with these tables as early as is feasible.

Table 1a. Thinning regimes prescribed for established *P. patula* plantations

Age (year)	Stocking (trees/ha)	Minimum spacing (m)
15 to 20	800	3.50x3.50
20 to 25	500	4.25x4.25
25 to 30	350	5.75x5.75
30 to 35	150	8.00x8.00

Table 1b. Thinning regimes prescribed for young *P. patula* plantations

Age (year)	Stocking (trees/ha)	Minimum spacing (m)
0 to 5	1600	2.50x2.50
5 to 10	1200	3.00x3.00
10 to 15	900	3.30x3.30
15 to 20	600	4.00x4.00
20 to 25	300	5.70x5.70
25 +	150	8.00x8.00

Table 2a. Thinning regimes prescribed for established *P. roxburghii* plantations

Age (year)	Stocking (trees/ha)	Minimum spacing (m)
15 to 25	800	3.50x3.50
25 to 35	500	4.50x4.50
35 to 45	350	5.75x5.75
45 to 55	150	8.00x8.00

Table 2b. Thinning regimes prescribed for young *P. roxburghii* plantations

Age (year)	Stocking (trees/ha)	Minimum spacing (m)
0 to 5	1600	2.50x2.50
5 to 15	1200	3.00x3.00
15 to 25	900	3.30x3.30
25 to 35	600	4.00x4.00
35 to 45	450	4.70x4.70
45 to 55	250	6.30x6.30
50 to 60	150	8.00x 8.00

Annex 2

Impact of Thinning on Pine Plantations in Kabhre and Sindhu

Annex 2: Impact of Thinning on Pine Plantations in Kabhre and Sindhu

Introduction

While NACRMLP has not had the opportunity to assess the extent of the pine plantations in Kabhre Palanchok and Sindhu Palchok districts, various prior estimates indicate that there could be over 20,000 ha planted and surviving. These estimates suggest that *P. patula* plantation occupies the largest area followed by *P. roxburghii*; and *P. wallichiana*, predominates at higher altitudes. These plantations were established by the Afforestation Division of the Department of Forest (DoF) in the beginning and later on from 1978 by the early phases of Australian assistance to the forestry sector in Nepal. Initially pine was the favoured as it is less vulnerable than other species to be damaged by grazing animals and can grow in degraded areas with poor soils. Moreover, *P. patula* grows fast at altitudes from 1500 to 2500m and can quickly build up greenery in a barren area. Its high survival rate--more than 80%--is another plus point (see Figure 1). The management of these plantations thus far has been very basic: little silviculture or harvesting has been undertaken. However, some CFUGs have thinned their forests according to a regime recommended by the Project and the DFO and endorsed by the Project Coordination Committee (PCC) chaired by the Secretary of the Ministry of Forest and Soil Conservation (MFSC) and attended by the Director General of the DoF and other senior officials.

A study done by Steve Hunt *et al.* (2001)* showed that there is an inverse relationship between stocking density and growth, i.e. as stocking increases, growth decreases. Delaying thinning results in a significant loss in opportunity costs: between Nepalese Rupees (NR). 15,000 and 20,000 per hectare every year. There is still much room for further improvements in forest management in order to improve the livelihoods of the poor and the disadvantaged and also to promote environmental conservation.

The Need for Thinning

Thinning is a forest management practice generally performed at some points in time during the course of the growth and development of both natural and planted pine stands. It can be defined as the calculated removal of certain trees from an existing stand and is usually conducted with a specific objective in mind. Field observation shows that small *P. patula* trees are often diseased and even dying in stands where the stocking is too high. According to Dickens *et al.*, over-stocking of stands puts trees under immense stress as they have to compete for the water, sunlight and nutrients they need to grow. Thinning relieves that pressure*.

Except for the thinning regimes for *P. patula* and *P. roxburghii* recommended by Hunt *et al.* (2001) no other significant studies have been conducted on suitable thinning regimes for or the effect of thinning in pine plantations in Kabhre Palanchok and Sindhu Palchok. The lacuna may be due to how recent the plantations are; 25 to 30 years is not enough

* Hunt, Steve *et al.* "Minimizing the Cost of Overstocking: Towards a Thinning Regime for Community Managed Pine Plantations in the Central Hills of Nepal." in *Journal of Forestry and Livelihood*, Vol. 1, July 2001.

* Dickens, David. *et al.* "Pine Plantation." in *Forest Stewardship Journal*.

time to gain adequate experience or to carry out long-term experiments over a whole rotation.

There are, however, some detailed studies of thinning and the effects of varying initial spacing, for example for *P. caribaea* in Surinam and *P. patula* in southern Tanzania and East Africa as a whole. In South Africa, Craib (1934, 1939, and 1947) worked on thinning regimes for the sub-tropical pines *P. elliottii*, *P. patula* and *P. taeda*. On the basis of past work done in various countries, Hunt and Dangal (2001) have recommended thinning regimes for *P. patula* and *P. roxburghii* in Kabhre Palanchok and Sindhu Palchok. Already five years old, these regimes need to be up-dated.



Chaubas before 1978 (Barren Land)



Chaubas in 1997 (After Plantation)

Comparison of land use in the Chaubas area of Kabhre Palanchok District before and after afforestation

Objective

The main objective of this study was to demonstrate the impact of thinning on pine plantation forests by comparing the differences in the growth increment of thinned and un-thinned plots.

Methodology

Study Site

This study was conducted in the following three community forests (CFs) in Kabhre Palanchok and Sindhu Palchok districts.

Gaurati Community Forest. This 102.24-ha, 10-block CF is located in Pipaldanda Village Development Committee (VDC) at the Chautara ridge of Sindhu Palchok district. Plantation took place between 1974 and 1982, and then the forest was handed over to a CFUG in 1990. The group has revised its operational plan (OP) thrice. Blocks 1 and 5 were thinned in 2000. Block 1 was used to collect core samples for a thinned plot, while Block 2, an un-thinned area, was used as the control.

Lankuri Community Forest. This 63-ha, five-block CF is located in Chaubas VDC of Kabhre Palanchok District. It was planted in 1981 and has been thinned thrice, in 1996, when handover to the CFUG took place, 1999, and 2001. Block 1 was chosen for a sample of thinned plantation.

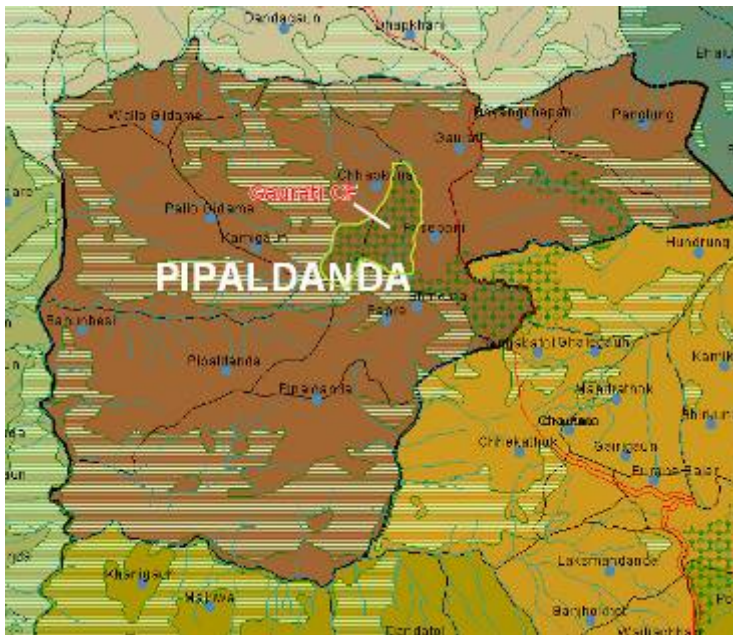
Chapani Community Forest. Located in Chaubas VDC of Kabhre Palanchok District, the 77.5 ha of this CF is divided into eight blocks. It was handed over to the CFUG in 1990. Core samples from Block 1 were taken as an un-thinned area.

Sampling Design

The thinned and un-thinned plots of *P. patula* plantations were selected in consultation with local field staff of the Project and the DFO. To ensure that climatic and edaphic conditions and site quality were similar, the sample plots chosen were in close proximity.

P. patula trees were sampled from thinned and un-thinned areas of Gaurati CF, from a thinned block in Lankuri CF and from an un-thinned block in Chapani CF. For samples from thinned forest; circular plots 0.1 ha in diameter were defined. Another 20 plots were delimited in un-thinned forest area. All plots were randomly selected from the block. The central tree of each sample plot was used as the tree for taking core samples. A total of 80 sample plots and 80 trees to be bored were selected (Figure 2).

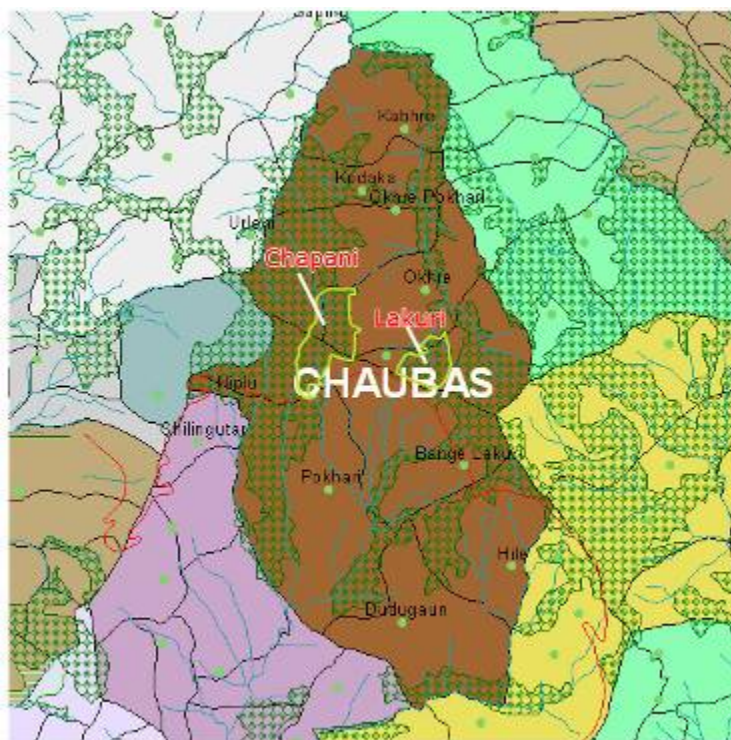
Using an increment borer, core samples were collected from the central trees as close as possible to the ground. They were taken directly through the centre of each tree to ensure that pith was included. Once a core of 0.5 cm in diameter had been removed, it was soaked in an alcohol solution to accentuate the contrast between annual growth rings. A calliper was used to measure the increment in the annual growth of each of the 80 central trees from thinned and un-thinned plots.



Pipaldanda VDC



Study Area in
 Sindhu Palchok and Kabhre Palanchok
 (Highlighting Pipaldanda and Chaubas VDCs)



Chaubas VDC

Maps of study area (Pipaldanda and Chaubas VDCs)

To find out the degree of stocking, all the trees within a 100-sq. m circular plot (radius of 5.64m) were counted. The Diameter at Breast Height (DBH) of all the trees within the sample plots were measured to find out the basal area. The greatest height of the trees within the sample plots was also measured. Early regeneration was counted within a circular plot of 10 sq. m (radius 1.78m), and the height and diameter of established regeneration were also measured within a circular plot of 25 sq. m (radius 2.82 m).

For each sample plot, the following data were collected and recorded: name of CF, block number, date of sampling, year of plantation, aspect, DBH and height of sample tree, diameter at the increment core, stocking per hectare, crew name and date. The field survey, core extraction and annual ring measurement processes are shown in the annex 1.

Data Analysis

Each sample core was examined to determine the increments between annual growth rings. A correlation analysis was carried out to examine the relationships among different variables. Simple statistical analysis was also done to find out the basal area, the average diameter and height of the trees in a plot, and the stocking of each of the 80 samples.

Results and Discussion

Increment

The results shown in Table 1 demonstrate that the annual growth increment in both thinned plots, those in Lankuri and in Gaurati, is greater than that in the un-thinned plots of Gaurati and Chapani (see Figures 4 and 5 and Annex 2). On average, the difference is 15%. Lankuri CF, where the highest increment was measured, has been thinned three times: in the 15th, 18th, and 21st years after plantation. The increment in Gaurati, which was thinned only once, is significantly less than that of Lankuri and only slightly greater than the un-thinned samples in the same CF (see Figures 6 and 7 and Annex 2).

Stocking

The average stocking in the thinned plots (460 trees/ha) is about 40% that of the un-thinned plots (1127 trees/ha). Lankuri, the plot that has been thinned thrice, registered the lowest stocking, just 370 trees/ha, while Chapani had the greatest density, 1385 trees/ha. According to recommended thinning regime for *P. patula*, there should be just 350 trees/ha; thus, even the thinned plots are overstocked (see Annex 3)—by almost 10% in Lankuri and over 35% in Gaurati.

Summary of sample plot data

Parameter	Unit	Thinned plots			Un-thinned plots		
		Lankuri	Gaurati	Average	Chapani	Gaurati	Average
Stocking	no. of trees/ha	370	550	460	1385	870	1127
Cumulative increment of core sample tree	mm	198.8	163.2	181	148.9	159.1	154
Basal area	sq. m/ha	30	34.5	32.25	53.4	39	46.2
Average diameter at breast height within sample plot	cm	31	28.31	29.65	20.67	23.94	22.3
Average height of trees within sample plot	m	19	21.47	20.23	17.65	21.1	19.37

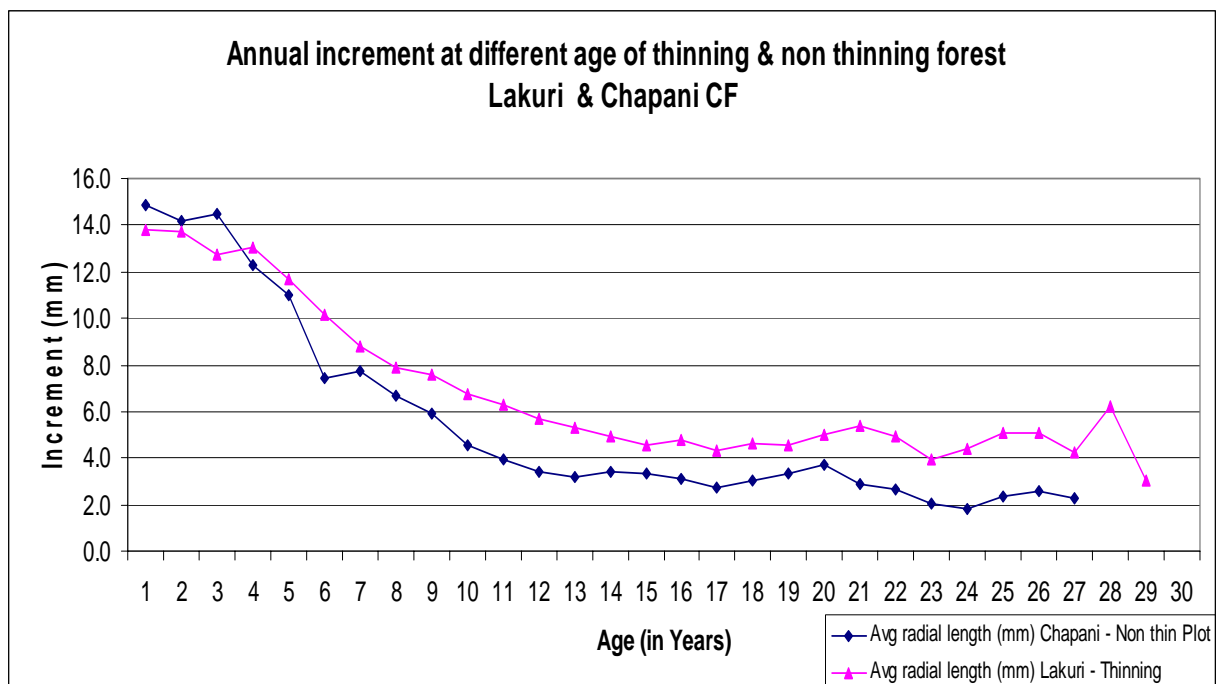
Parameter	Unit	Thinned plots			Un-thinned plots		
		Lankuri	Gaurati	Average	Chapani	Gaurati	Average
Early regeneration	no. of trees/ha	<i>P. patula:</i> 4000/ha broad-leaf: 5,000/ha	<i>P. patula:</i> profuse broad-leaf: 5,500/ha			<i>P. patula:</i> 6000/ha	
Established regeneration	no. of trees/ha	Not significant	Not significant				

Basal area, average diameter and average height

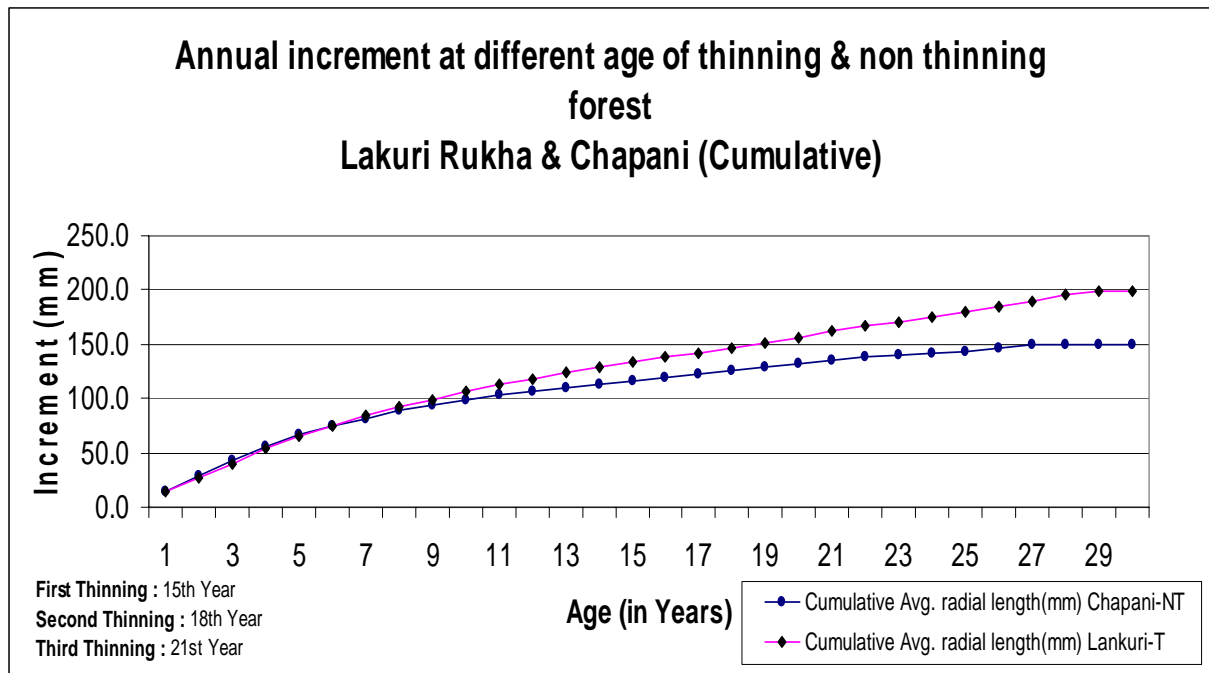
The basal areas of both thinned plots are less than those of the un-thinned plots. Their average area is about one-third less than that of the un-thinned plots. The average diameter of trees in un-thinned plots is 37% less than that in thinned plots. The difference in height is much less: un-thinned trees are, on average, 9% shorter.

Regeneration

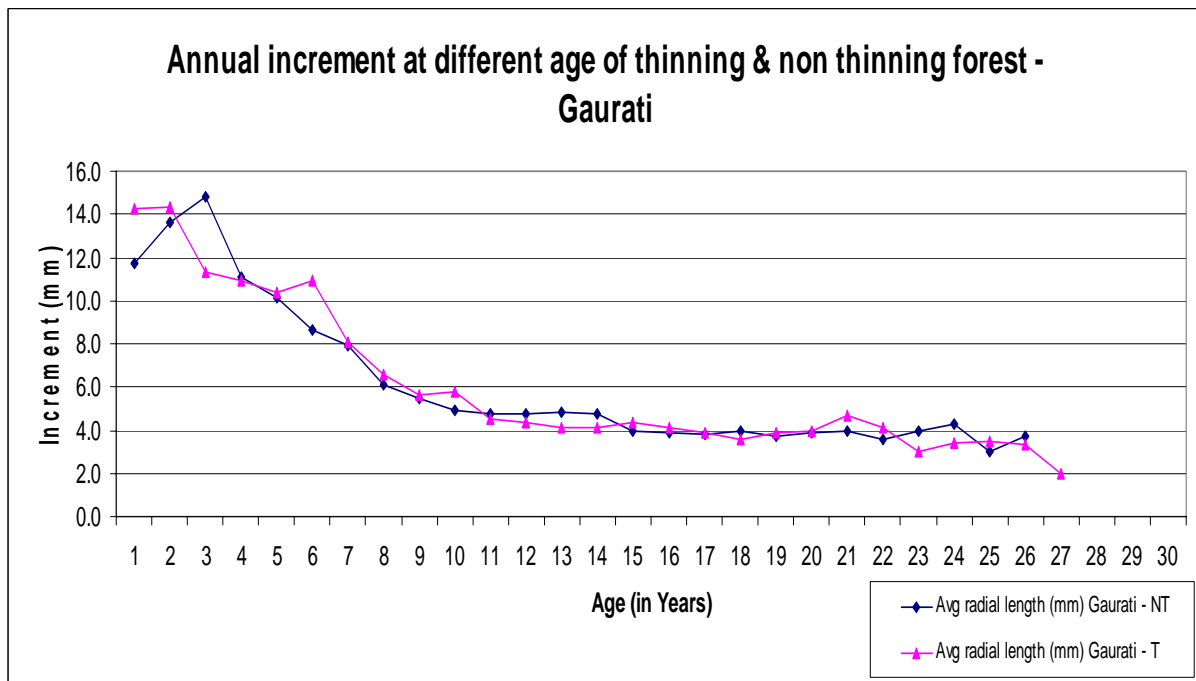
Early regeneration of *P. patula* is profuse in thinned areas where there have been fires in the past and where the canopy has, in consequence, been opened up. In some thinned areas, the regeneration of broad-leaf species like *Schima wallichii* (*chilaune*), *Fraxinus floribunda* (*lankuri*), *Lyonia villosa* (*angeri*) is also found. No significant presence of any kind of established regeneration was found in either thinned or un-thinned plots except in a very few open areas



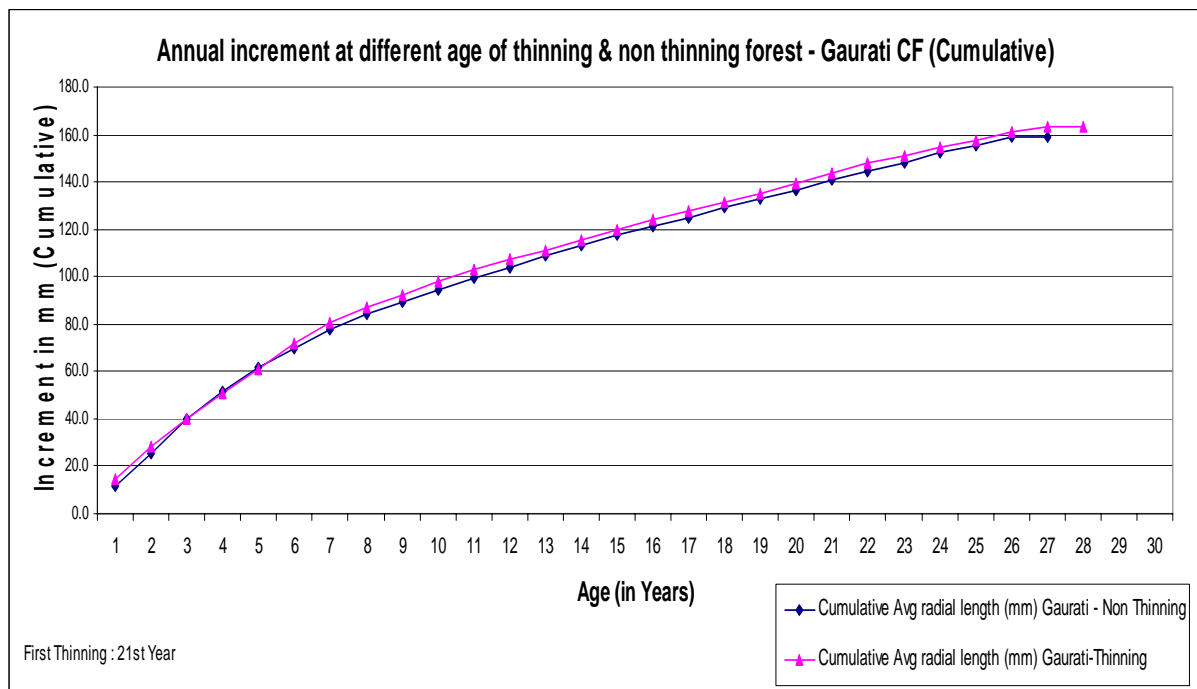
Annual growth increments of thinned and un-thinned plots in Chaubas, Kabhre Palanchok



Cumulative increment of thinned and un-thinned plot in Chaubas, Kabhre Palanchok



Annual increment of thinned and un-thinned plots in Chautara, Sindhupalchok



Cumulative increment of thinned and un-thinned plot in Chautara, Sindhu Palchok

Recommendations

It is evident from the study that there was a significant increase in the annual growth increment of remaining pine trees in sample plots in Kabhre Palchok and Sindhu Palanchok when thinning operations took place. These forests should be managed according to recommended thinning regimes in order to ensure the greatest biological and long-term economic benefits are reaped. It is imperative that silviculture prescriptions for thinning be included in CFUG operational plans.

Most CFUGs are protection-oriented and are not convinced about the necessity for thinning regimes. A two- or three-day orientation workshop should be organised in both districts to make CFUGs and other stakeholders aware of the positive impacts of thinning on their community forests. Judicious marketing linkages should be established before applying thinning regimes as it is possible that small trees can be harvested at the same time.

Field survey, core sampling, measurement of annual growth rings and comparison of thinned and unthinned plots



Using an increment borer to take a core sample close to the ground



Taking the core out of the borer



Measuring the dbh of a tree in a sample plot



Core samples soaking in alcohol solution



Marking annual rings for measurement



Measuring annual rings using a caliper



Un-thinned plot in Rachhama CF in Chaubas



Thinned plot in Gaurati CF in Chautara



Un-thinned plot in Chapani CF in Chaubas



Thinned plot in Lankuri CF in Chaubas with profuse regeneration due to fire

Limitations

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