Managing smallholder teak plantations

Field guide for farmers

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Foreword

Teak (*Tectona grandis* L.f.) is a highly valuable timber species, sought by wood industries to produce good quality furniture and wood for house construction, carving, shipbuilding and many other purposes. In Indonesia teak was first established on plantations by a state-owned company. Today it is also widely cultivated by millions of smallholders who grow the trees on their privately owned plots. Gunungkidul district, in the province of Yogyakarta in central Java, provides a good example; teak has been widely planted by farmers there since the 1960s. Today, the tree has become an important household asset and often serves as the household savings account.

Farmers in Gunungkidul district cultivate teak in primarily two ways: on wood lots and in intercropping systems. Timber is the main product in wood lots known as *kitren*. Intercropping systems, called *taungnya* or *tumpangsari*, plant teak amongst agricultural crops. These mixed systems or homegardens are also called *tegalan* or *pekarangan*.

Most farmers still use a management approach of 'plant and watch them grow' which limits productivity and the quality of their teak. This laissez-faire cultivation practice could be improved by applying appropriate silviculture techniques to improve land productivity and timber quality, thereby increasing farmers' net profits from their teak-growing enterprise.

Efforts to develop smallholder timber plantations, for teak in particular, are of great interest to many organisations, including: the Center for International Forestry Research; the World Agroforestry Centre; Winrock International; the Forestry Research and Development Agency of the Ministry of Forestry; Kelompok Kerja Hutan Lestari, an NGO consortium led by the Gunungkidul district government; the International Center for Applied Finance and Economics, part of Bogor Agricultural University (InterCAFE-IPB); and Australian National University. At CIFOR, for example, the theme is in line with the centre's mission and falls within the research activities carried out under the theme, 'Improving livelihoods through smallholder and community

forestry'. The Australian Center for International Agriculture Research (ACIAR) supported these efforts by funding the project, 'Improving Economic Outcomes for Smallholders Growing Teak in Agroforestry Systems in Indonesia', ACIAR project No FST/2005/177. This guide was developed and disseminated with the support of the grant.

This book was produced to meet the needs of farmers and practitioners for a practical guide about establishing and managing smallholder teak plantations. Smallholder teak plantations have different characteristics from plantations on a larger scale. Smallholders must manage their plantations accounting for specific challenges not covered by existing guidelines: how to space trees on rock and hill lands, or how to thin in stands of unevenly aged teak trees. We cover specifics like these in this manual. Adoption of a need-based cutting system and some traditional wisdom are also included.

Techniques presented in this guide are drawn from many sources: the available literature; personal communications with experts, researchers and teak management practitioners from Perum Perhutani, a state-owned timber company; experiences of farmers and forestry extension officers in Gunungkidul district; and the authors' own experiences. That general information is complemented with lessons learnt from other activities of this project.

We expect that the book will be useful not only for teak farmers at the project sites in Gunungkidul district but also for any smallholders growing teak, policy makers, researchers, extension officers, and all parties who are interested in developing smallholder teak plantations.

Dede Rohadi
Project Leader

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1
Introduction

Why are smallholder teak plantations important?

- Teak (*Tectona grandis* L.f.) is a high-quality timber species of the Verbenaceae family. The species' natural distribution includes India, Myanmar and Thailand.
- Teak was first brought to Indonesia and planted by Hindu missionaries who came to Java in around the second century AD. Today teak is a profitable plantation crop promoted by government agencies, the private sector and farmers.
- Teak plantations are widely established across Indonesia; in some places they have become an inseparable part of local cultural and socioeconomic systems.
- In Indonesia, teak plantations have the potential to improve livelihoods of farmers, traders and wood processing industries. Plantations play an important role in local and national economic development.
- The markets for teak and products made from teak are diverse, including overseas and domestic buyers.

Figure 1.1 Smallholder teak plantations are beautiful, beneficial for the environment and an important source of income for small-scale farmers.

- Even though the time between planting and harvesting, the rotation period, for teak is long, plantations also provide environmental services including water conservation and support for beneficial microclimates.
- Teak products are durable, providing service to consumers for a long time.
- Almost all parts of teak trees are useful. In some areas people also seek out caterpillars (*Hyblaea puera*) found on teak as a source of protein.

For whom is this manual intended?

This manual is primarily intended for smallholder teak farmers. It is also expected to be useful for extension officers, researchers and policy makers.

Why is this manual needed?

- Smallholders generally manage teak plantations with traditional, non-intensive practices, resulting in timber yields of low quality and quantity.
- Farmers have limited access to technical information and extension services; in most cases accepted standards for best practices are not used to manage smallholder plantations.
- The most recent information on teak management is written in scientific language, difficult for non-scientists and inaccessible to farmers.
- This manual, written in practical, plain language and specifically designed for smallholder teak farmers, fills that gap.

What is the scope of this manual?

- This manual was written as a guide to improve the quality of smallholder teak management through the application of appropriate silvicultural practices, from seed selection, seedling production, planting and plantation maintenance through to harvesting.
- The teak management techniques presented in this manual are simple, cost-effective, and easy to be applied by farmers.
- This manual includes guidelines for the development of smallholder teak plantations, either monoculture (single species), mixed plantings of multiple species, or agroforestry (trees mixed with annual or seasonal crops).

2
Teak silviculture

What is silviculture?

Silviculture is:

- The science and art of forest management based on knowledge of tree growth.
- It includes species and variety selection, seed and seedling management, site preparation, spacing and planting patterns, fertilising, pruning, thinning, forest health monitoring and management, and harvesting.
- It also includes management for nontimber forest products, conservation and environmental services.

Is there a link between silvicultural activity and teak wood value?

The value of teak wood is determined by tree attributes: diameter and straightness of the stem, length of clear bole, wood fibre straightness, and presence or absence of wood defects, such as those caused by branch knots, disease or insects. Appropriate silvicultural treatments improve the quality of teak trees and increase the value of their timber. The following examples illustrate five typical silvicultural treatments.

- Using improved germplasm produces trees that grow quickly with straight stems and other desireable attributes.
- Pruning young trees produces clean, knot-free stems and long, clear boles.

- Thinning plantations reduces competition between trees for soil nutrients, water and sunlight, accelerating the growth of the stem diameter. Removing slower growing, diseased or poorly formed trees during periodic thinnings allows the faster growing, better quality trees to achieve their growth potential.
- Fertilising will accelerate tree growth resulting in higher yields and logs with larger diameters.
- Controlling pests and diseases will ensure healthy trees with few defects in the wood.

What activities are included in the silviculture of teak?

These general silviculture management techniques lead to specific activities.

- Selecting good quality seed and propagating quality seedlings.
- Preparing land for planting in ways that promote tree survival and growth.
- Spacing seedlings at an optimum distance between trees for easy maintenance and fast growth.
- Fertilising to make essential nutrients available and improve tree health and growth rates.
- Pruning branches from the boles starts when the trees are between 3 and 5 years old. Pruning increases the clear bole length and reduces the occurrence of knots, increasing the quality and value of the timber. Pruning continues regularly halfway up the bole's final height.

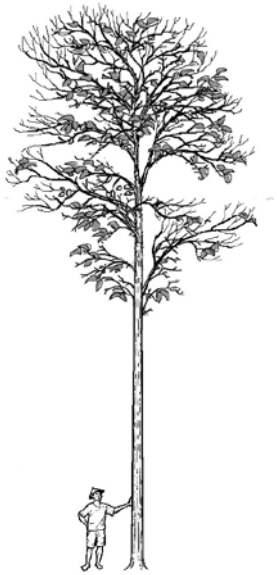


Figure 2.1 Appropriate silvicultural techniques produce a high quality teak tree

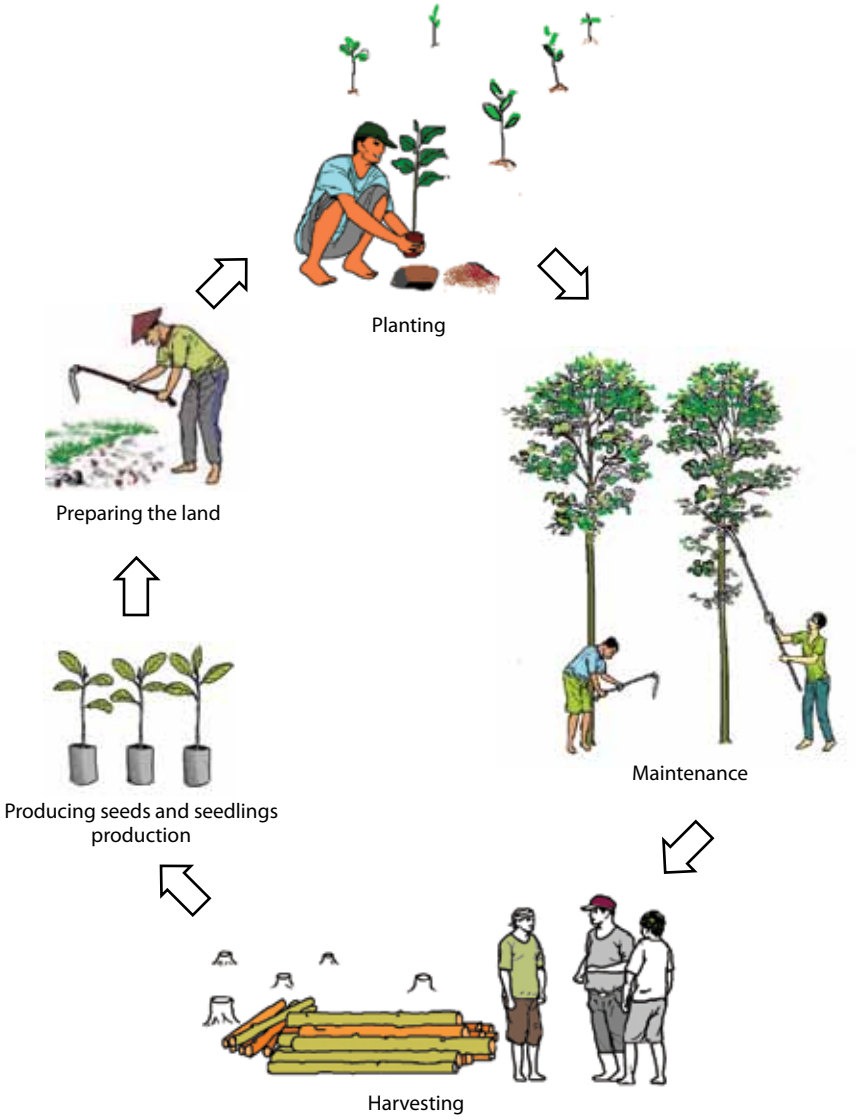


Figure 2.2 Activities in teak silviculture

- Thinning trees increases the space between trees as they become larger, reduces competition for nutrients, water and sunlight and ensures faster growth, greater volume and better wood quality in the remaining trees.
- Preventing and controlling pests and diseases results in healthier, more productive and higher value plantations.
- Harvesting mature trees for home use or market sale.

3

Seeds and seedlings

Why do seeds need to be prepared?

- The growth and physical appearance of trees are influenced by characteristics they inherit from the parent trees and the situation in which they grow. These are called genetic and environmental factors.
- A healthy stand of fast-growing trees that will yield high quality timber can be obtained from healthy, fast-growing seedlings derived from good quality seed.
- Good quality seedlings will show maximum growth when planted on suitable land and fair growth on less suitable land.
- In contrast, poor quality seedlings will grow more poorly on any type of land.
- When seedling production is well planned and conducted, smallholders have good quality seedlings suitable for the planting site and planting time.

Figure 3.1 Teak seeds and seedlings

3.1. Seed collection

Where can we obtain good seeds?

- The best seeds should come from seed orchards, including hedge seed orchards, seedling seed orchards and clonal seed orchards. Seeds from these sources are of limited supply and expensive.
- Seeds from seed production areas, identified seed stands or selected seed stands are likely to be more easily available to farmers or institutions and programmes that support farmers.
- When buying seed, the seed should come from a certified superior or reliable source.
- Seeds should come from sources with ecological conditions similar to the planting location, including altitude, climate, and soil type. For example, farmers in Gunungkidul should use seeds sourced from similar conditions: dry land, limestone soil, 0–400 metres above sea level.
- If it is difficult to get seeds from certified seed sources, the easiest and most cost-effective way to obtain seeds is by collecting them from the best quality seed trees (mother trees) in the local area.

Figure 3.2 Teak seed tree, a plus tree in Perum Perhutani

What are seed trees?

Seed trees are trees selected and maintained for producing seeds. These trees are also called seed sources.

Seed source classes

These seed sources can be:

- Individual trees on agricultural land or in natural forest or
- A group of trees that grow together in one area.

The Ministry of Forestry Decree No: P.01/Menhut-II/2009 classifies seed sources for forest plantations into seven categories. The quality of seed improves through this ranking, with identified seed stands being of lowest quality and a hedge seed orchard being of highest quality.

1. An identified seed stand (ISS), provides source seeds of average quality. This stand can be located in natural forest or on a plantation. The location is recorded appropriately.
2. A selected seed stand (SSS) provides source seeds with better quality than the average stand.
3. A seed production area (SPA) is a stand established specifically as a source of seeds. An SPA can also be created by thinning out poor quality trees from an ISS or SSS.
4. A provenance seed stand (PSS) provides seeds generated from seeds that were collected from a natural distribution area, the provenance.
5. A seedling seed orchard (SSO) provides seeds generated from the seeds from 'plus' trees, which are select trees with good performance.
6. A clonal seed orchard (CSO) provides seeds generated from vegetative materials (usually stems, leaves or roots) of plus trees.
7. A hedge seed orchard (HSO) provides vegetative materials, usually for cuttings or tissue culture, generated from seeds or grafts from trees in a CSO or SSO.

In Indonesia, the first three classes, identified and selected seed stands and seed production areas, are accredited by the Forest Trees Seed Institute (Balai Perbenihan Tanaman Hutan, or BPTH) of the Ministry of Forestry. Provenance seed stands and the three orchard classes are collaboratively accredited by BPTH and the Forestry Research and Development Agency (FORDA) of the Ministry of Forestry.

How can we select a seed tree?

Select a tree that demonstrates superior performance compared with the trees surrounding it, looking for these characteristics:

- above average tree height and stem diameter,
- straight stem,
- long, clear bole that will get a good price at market,
- uniform crown, without heavy branches or double stems,
- free of pests and disease,
- good quality timber, meaning it is round,
- a mature tree, that can produce ample quantities of seeds.

In unevenly aged teak stands, do not select a seed tree based on stem diameter alone, since diameter does not necessarily indicate better genetic quality. It could just indicate an older tree.

In evenly aged stands, diameter and tree height are the important characteristics for selecting seed trees.

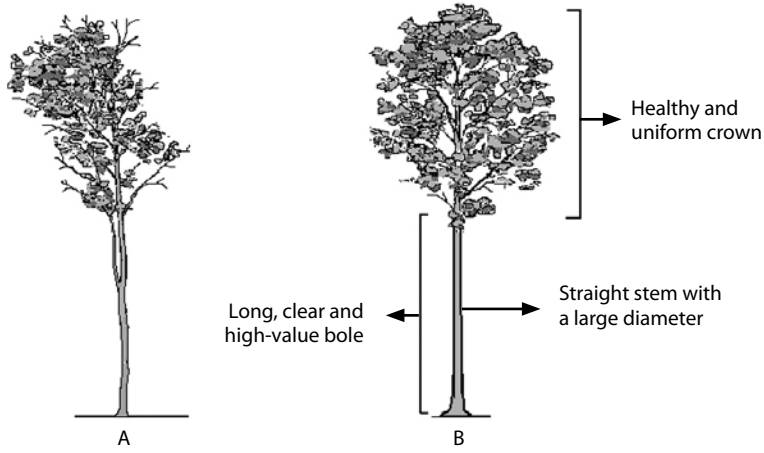


Figure 3.3 Selecting appropriate seed trees
A An unsuitable teak seed tree
B A suitable teak seed tree

Can seed trees be selected from the garden or forest surrounding us?

Yes, as long as they meet these requirements:

- The seed tree must grow with other adult trees within 100 m. Do not select a seeds tree that grows alone, even if this tree is large and straight. The seeds of trees that grow alone are to be produced from self-pollination hence the seeds' genetic quality may be poor.
- Make sure that seed trees are selected from a garden where most of the trees are well formed and disease free.
- If farmers establish teak plantations using seeds of a single tree, then that seeds should not be from a tree in that plantation. Those trees are closely related, so the genetic diversity is likely to be poor though its appearance looks good.

When and how should the seeds be collected?

- Harvest teak fruits when they are a dark brown colour because then they are ripe. A white or light colour indicate that the fruits are unripe.
- Collect seeds from mother trees that have already produced healthy seed crops for at least two or three years.
- Teak trees usually begin to produce viable, healthy seed crops when they are around 12–15 years old. Teak trees of coppice origin may produce seeds at a younger age.
- To improve the range of seeds you collect, take seeds evenly from all parts of the canopy, the top, sides and bottom. These parts may be pollinated at different times with pollen from different trees.
- Clean the ground around the mother tree. Place a sheet of plastic or other suitable material, a tarpaulin, on the ground under the canopy of the mother tree to easily collect the seeds that fall and to keep them clean.
- Climb the selected tree and shake the branches. Ripe seeds will fall on the tarpaulin.

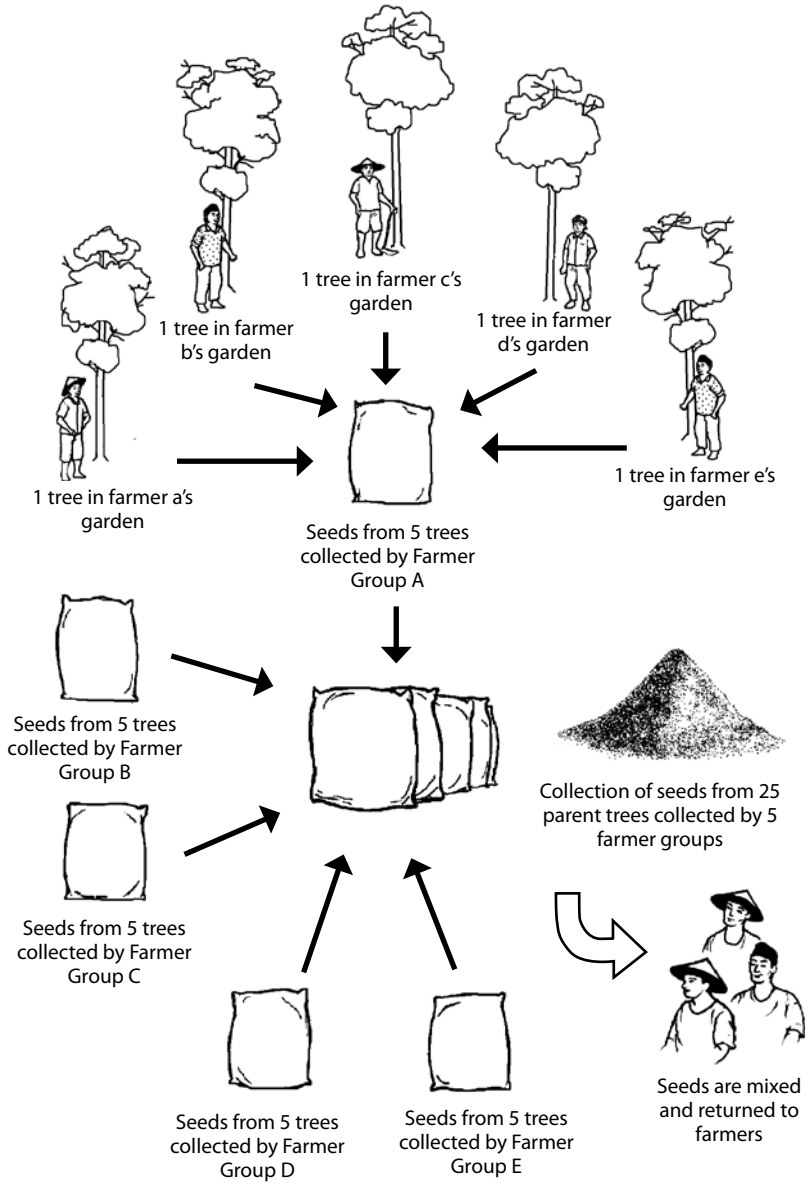


Figure 3.4 Collecting quality seed in collaboration with a group of farmers

- Only collect seeds that fall on the tarpaulin. Other seeds that are already on the ground may not come from the selected seed trees. Or they may be dirty or infected with disease or insects.
- However, collecting seeds from the ground within seed stands, seed protected areas or seed orchards will give you good seeds. All trees in these stands are considered to be quality mother trees, so each seed is expected to come from the breeding of good parent trees. These naturally fallen seeds should be stored in a separate container without mixing them with other seeds that might contaminate them.
- Gather seeds that are generated from a minimum of 10 trees. It's better to collect seeds from 30–50 trees for the best genetic diversity.
- Never collect seeds from only one tree, even if that tree can provide the quantity required. Seeds from a single tree will usually produce a stand of trees of generally low quality. These seeds, if planted together in one area, may produce a plantation that is not resistant to pests, diseases and climate change.
- Avoid creating your seed trees using seeds from closely related parents. Collect seeds from good seed trees that are at least 50 metres apart.
- Farmers and farmer groups benefit from collecting seed collaboratively. For example, each farmer or farmer group collects seed from five seed trees. The seed from all 25 seed trees is mixed together. Each farmer or farmer group receives the same quantity of seed they contributed. Each farmer or group then has seed from at least 25 good quality parent trees that are not closely related.

3.2. Seed handling

How to handle the seeds

- Choose only healthy seeds from ripe fruit.
- Lay the seed out in the sun over a flat area to dry.
- Dry the seeds for 1–2 days in sunny weather. This will produce seeds with a water content of about 12%.
- Clean the dried seeds by peeling off the seedcoat and removing any dirt or litter mixed in the seed.
- Perforated (pockmarked) seeds do not always indicate poor quality of seeds. These seeds are often easier to germinate because of natural scarification.
- One kilogram of teak seeds usually contains about 1500 seeds. Seed size is not an accurate indicator of seed quality.

Figure 3.5 Pockmarked seeds due to natural skin trimming

What is the right way to store seeds?

- Store dried seeds in a sealed container in a dry and cool storage area. Use an air-conditioned room, if possible.
- Seeds can be stored for up to 2 years.

4

Seedling production

4.1. Seedlings propagated from seed

How to germinate seed

- Typically teak seed is difficult to germinate. This is because it is difficult for water and air to penetrate the seed coat. Water and air are the main requirements for germination.
- For rapid seed germination, specific conditions and treatments are required to prepare the seed coat to allow water and air to penetrate.
- Treating the seed before sowing is essential for rapid and uniform seed germination.

How can we prepare the seed coat before sowing?

To prepare the seed coat and germinate the seeds, soak the seeds in one of these six ways.

- Soak the seeds for 3 days (72 hours) in cold running water, drain the seeds and allow them to dry for 2 days.
- Soak the seeds for 3 days in a container of cold water, but change the water daily. Allow them to dry for 2 days.
- Soak the seeds in cold water for 1 day, then sun dry them for 1 day. Repeat the treatment 2 or 3 times.
- Soak the seeds in cold water for 1 hour, then soak them in hot water for 1 hour and then air dry them for 7 days.

- Soak the seeds in a concentrated solution of sulphuric acid (H_2SO_4) for 15 minutes, then wash them with water, and dry for 1 night.
- Soak the seeds in cold water for 2 nights, then sun dry for 1 day.

These treatments can also be combined to obtain maximum seed germination. Testing with small volumes of seed to identify the best combination is recommended.

How to sow seed

1. Prepare the sowing medium. Sand is preferred because it drains well but also retains water. The sand should not be too coarse or too fine, as sifted sand for stucco wall construction, and should not include organic material or soil.
2. Sterilise the sowing medium by sun drying and treat it with a nematicide to kill parasitic nematodes.
3. Water the sowing medium evenly.
4. Place the treated seeds into the sowing medium, with the micropyle facing down.
5. Plant the seeds as deep as the seed diameter, and then sprinkle sand over the seeds to cover them with a top layer of about 1–2 cm.
6. Cover the medium with straw. This prevents the seeds from being displaced during watering (See Figure 4.1).
7. Water the medium.
    - Cover the sowing bed with a plastic cover, but during periods of high temperature, such as sunny weather in the dry season, remove the cover.
    - The sowing bed must be weeded and watered daily to avoid competition and to keep the medium moist.
8. Five to 7 days after sowing the seeds should begin to germinate. Normally germination does not occur uniformly. Some seeds may not germinate until 100 days after sowing. The germination rate

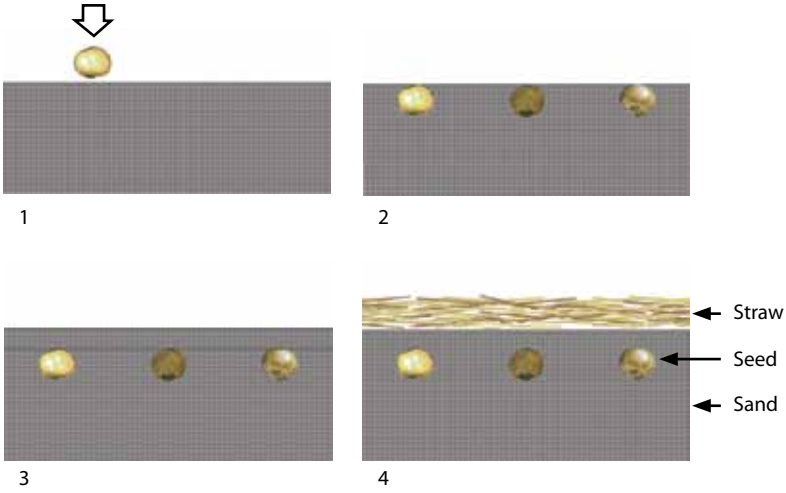


Figure 4.1 Seed planting technique in sand medium

and percentage are determined by the age of the seed, the way the seed is treated with drying and soaking, and conditions in the sowing bed.

How to transplant germinants

1. Prepare a nursery medium using topsoil and compost at a ratio of 2 parts topsoil to 1 part compost.
    - Two other ratios also work. Combine 2 parts manure with 3 parts topsoil, or 2 parts compost with 1 part topsoil and 1 part rice husks.
2. Mix the components to a uniform consistency. Add a fungicide at prescribed rates to create a sterile environment for the germinants: place the medium in polybags.
3. The germinants can be transplanted 3–5 days after germination or after a pair of leaves have formed but are not yet fully open (See Figure 4.2).

Figure 4.2 Germinated seeds ready to be transplanted

4. Transfer the germinants to polybags in the morning before 10:00 or in the afternoon after 15:00 when temperatures are low.
5. To remove the germinants from the sowing bed, first lift the medium around the germinants' roots using a flat-shaped twig or bamboo.
6. Lift the germinant by gently holding its leaf or the seed.
7. Transplant germinants immediately after lifting to avoid root desiccation. Only a few germinants, about 10, should be lifted and exposed to desiccation at any one time. When many germinants are to be transplanted; wrap the germinants in moist newspaper or cloth, or store them in a water-filled container between lifting and transplanting.
8. After transplanting, water the medium and seedlings evenly.

4.2. Seedlings raised from shoot cuttings

Where can we find good cutting materials?

- Shoot cutting materials can be obtained from coppices, seedlings or a hedge orchard.
- The cuttings should originate from the best quality trees or selected clones.

What is a clone?

A clone is a group of trees or seedlings that are genetically identical, produced through vegetative propagation rather than from seeds from a single tree. Clonal propagation can be done by cutting, grafting or tissue culture.

Figure 4.3 Teak hedge orchard, shoot cuttings and planting method

How to choose and prepare plant material for cuttings

- Choose shoots for cutting that are about 2–3 weeks old with these characteristics: the shoot is still hairy, somewhat cylindrical and bright green with three pairs of leaves and is 5–7 cm long.
- Choose shoots that grow straight up (orthotropic shoots) and avoid shoots that grow sideways.
- Remove the shoots and trim each leaf to retain about one-third.
- Cut at the base of the shoot obliquely with a sharp knife or cutter.
- Dip the base of the cutting in a solution of indole butyric acid (IBA) for 5–10 minutes. Prepare this solution by dissolving 0.02 g of IBA in 2 tablespoons of NaOH or alcohol, then mix it with 1 litre of water.

How to plant cuttings

- Prepare a planting medium containing a mixture of 2 parts sand, 3 parts compost and 1 part topsoil, then place it into a 10×15 cm polybag.
- Use polybags that are of transparent plastic so you can identify when roots have grown.
- Place the polybags in a flat and well-drained seed bed which is in a shady area or under a shading net.
- Make a planting hole in the mixture using a stick to avoid damaging the base of the cutting.
- Plant the shoot cuttings that have been dipped in the IBA solution in the hole.
- Water the cutting.
- Cover the cutting bed with a plastic cover placed 50 cm above ground level, as demonstrated in Figure 4.4.
- Good weather for rooting teak cuttings is when the humidity is above 80% and the air temperature is between 24°C and 32°C.

1 Create covering frame from bamboo and arrange polybags inside.

2 Seal both ends of the frame with plastic.

3 Cover the cuttings with plastic that opens and closes easily.

4 The sealed transparent plastic cover maintains high humidity within the cuttings bed.

Figure 4.4 Technique for covering cuttings bed with plastic

- Cuttings should be watered twice a day, once in the morning and again in the afternoon.
- If there is an indication of fungal attack, spray cuttings with a fungicide at prescribed rates.

Caring for rooted cuttings

Before planting in the field, gradually acclimatise the cuttings to dry and open conditions, which are different from the conditions under the plastic cover. Techniques for acclimatisation include:

- Separate rooted cuttings and place them in a separate bed in a shady area.
- Separate unrooted cuttings and place them in other beds to continue the rooting process.
- Keep rooted cuttings under a plastic cover for 3 days to adapt to the new conditions in the planting bed.
- Open the cover gradually at a rate of 10 cm per day. After 10 days the cover can be completely removed.
- Keep the cuttings in the shady area without cover for 2 weeks.
- Move the seedlings raised from cuttings to an open area until they are ready for planting.

4.3. Seedlings from other sources

Are there other techniques to produce seedlings?

Yes, seedlings can come from wildings and stumps. Several other techniques for propagating teak seedlings exist that require high technology and cost a great deal, such as tissue culture. Those techniques are not suitable for individual smallholders.

How can we prepare seedlings from wildings?

- Wildings are naturally regenerated seedlings that grow in or near teak plantations and gardens.

Figure 4.5 Wildings found in teak plantations

- Select wildings that already have 2–3 pairs of leaves, a straight and balanced stem and appear healthy and fast-growing.
- Collect wildings during the rainy season. Cut the leaves in half and prune some of the fibrous roots. Transplant the wildings immediately into polybags containing a medium as described above: 2 parts sand, 3 parts compost and 1 part topsoil.
- After 3–4 months in the nursery, wildings are ready for planting.

What is a stump?

- A stump is a seedling whose leaves and root hairs have all been removed, leaving only the main parts of the stem and roots.
- Bigger seedlings or wildings with trunk diameters of 2–3 cm make better stumps.
- Turning seedlings into stumps makes handling and transporting of large numbers of plants easier, as they are lighter and compactable when shipping.

How would we create stumps?

- Remove the seedlings from the soil medium.
- Cut the stem and fibrous roots. Leave the stem about 3-4 cm long and the roots about 15-20 cm long.
- Remove the root hairs.
- For shipping, wrap the stump in moist material such as banana bark or dampened newspaper.
- Plant the stumps in polybags and place them in a shady environment.
- If more than one shoot is growing from the stump, choose the shoot that is growing well as the main stem and prune the others.
- Stumps are ready for planting when the leaves and roots are growing well and are strong.

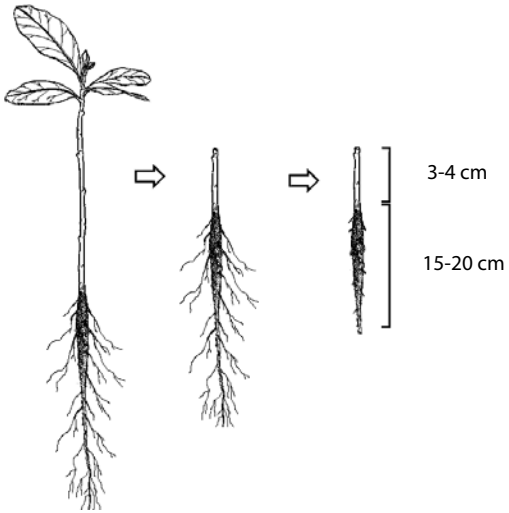


Figure 4.6 Technique for creating teak stumps

4.4 How to maintain seedlings in a nursery

- Maintenance activities include watering, fertilising, weeding, pruning, root pruning, spacing and controlling pests and diseases.
- Water twice a day in the morning and afternoon, or at least once a day, preferably in the afternoon.
- Fertilise the seedling bed 1 month after planting using NPK fertiliser. Repeat when seedlings are 2 months old using 2 g of NPK fertiliser per seedling, approximately ½ teaspoon).
- Remove weeds from in or between polybags as needed.
- Prune the seedlings once the seedling is 20 cm tall to remove old, dry, rotten or diseased leaves, leaving the top three pairs of leaves.
- Prune the roots that grow out of the polybags regularly to encourage roots to grow into the soil. Do the last cutting at least 1-2 weeks before distributing the seedlings.
- Increase the spacing between seedlings when the leaves of adjacent seedlings start to cover each other.
- Controlling pests and diseases is explained in more detail in Section 6.

Figure 4.7 Young teak seedlings in a nursery

When seedlings are ready for planting, what do they look like?

Stem diameter and seedling height are not the best indicators to determine seedling quality. Good quality seedlings that are ready for planting have three features:

- Strong roots with a porous medium. When seedlings are removed from the polybag, the medium and the roots maintain a cylindrical form which is porous and not compacted.
- A single, strong and woody stem. Seedlings are upright and strong, with a balanced stem diameter and height.
- Healthy new leaves with no evidence of harm from pests or diseases.

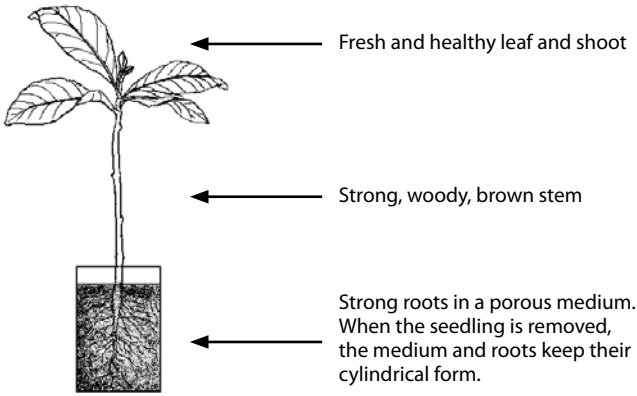


Figure 4.8 Features of a good seedling ready for planting

5
Planting

5.1. Designing a planting system

What planting system should farmers use?

- Several planting systems are appropriate for teak including monoculture (single species), mixed species and agroforestry.
- Consider land conditions and land use before choosing the best planting system for teak.
- Apply an agroforestry system on fertile soil because the benefits from land use can be maximised. Besides selling the timber produced, farmers can also sell or use the agricultural products.
- Apply a monoculture or mixed species system on infertile soil, rocky soil or rocky terrain to improve soil quality and to prevent landslides or erosion.
- Apply mixed species or agroforestry to increase diversity of products for short, medium and long-term revenue.
- If the land is far from the landowner's home, or the landowner does not have enough labour to conduct routine maintenance activities, monoculture or mixed species systems are more appropriate than agroforestry.

What is the monoculture planting system?

In the monoculture system only one species is planted. Landowners usually prefer this system when they

- do not need multiple products from the land, for example, agricultural crops,

Figure 5.1 A smallholder monoculture teak plantation

- have insufficient labour available to manage the land intensively,
- have extensive land, other jobs or other sources of income that meet household needs.

What are the advantages and disadvantages of a monoculture planting system?

- The advantage of a monoculture planting system is more timber volume and better and uniform quality timber can be produced from the same area of land, compared with the mixed species or agroforestry system.
- Monoculture systems are easier to manage because there is a single crop species.
- The disadvantage is that monocultures are more susceptible to pests and diseases.

What is an agroforestry planting system?

- In an agroforestry planting system farmers plant teak and agricultural or seasonal crops in one area.

- This system can be applied on or around farmland, including paddy fields.
- The advantage of an agroforestry system is that farmers gain short-term income from agricultural crops such as maize, peanuts, cassava, taro, patchouli and spices, such as turmeric, ginger and *temu ireng*; and medium- to long-term income from timber.
- Maintenance activities for seasonal crops like tillage and fertilisation benefit the growth of teak. For example, an experienced farmer can prune teak roots while tilling the soil for planting crops.

- Agricultural crops in the Solanaceae family (aubergine, for example) should not be planted when teak is still young because they are hosts for wilt (see Section 6).

Figure 5.2 A smallholder agroforestry teak system

- An agroforestry system can also combine teak with plantation crops, such as cocoa or palm oil.

What is a mixed plantation system?

A mixed plantation is land planted with various tree species, evenly or unevenly aged stands. The mixture of several tree species, with varying harvest schedules and canopy height, resembles a forest.

What are the advantages and disadvantages of a mixed plantation?

This planting system offers several advantages:

- more resistant to pests and diseases,
- better use of growing space and root system,
- variation in land can be used more effectively,
- more resistant to wind, and
- improves species diversity.

Figure 5.3 A mixed species plantation

- The differences in timber harvest cycles and harvest of nontimber products create a steady and diversified income stream over the short, medium and long term.
- This diversified production can reduce the market risk associated with single crop systems.
- This system has two main disadvantages:
  - If teak is planted closely with fast-growing species, such as acacia or sengon, the teak will face strong competition for nutrients, moisture and light resulting in slower growth.
  - Because of differences in production and rotation age, more caution is required when harvesting to prevent damage to surrounding trees.

What tree species combine well with teak in a mixed plantation?

The best tree species for intercropping with teak are species that are equally suited to the planting purpose and land conditions.

- Select tree species that are suited to the climate and conditions of the planting site. For example:
  - In highland areas, trees that intercrop well with teak include mindi (*Melia azedarach*), waru gunung (*Hibiscus macrophyllus*) or suren (*Toona* sp).
  - Teak on arid land are best combined with species that can grow well in dry areas, such as sandalwood (*Santalum album*) (See Table 5.1).
  - On relatively fertile land teak can be combined with fast-growing species, such as sengon (*Paraserianthes falcataria*) or gmelina (*Gmelina arborea*).
- Plan the species composition based on production periods and harvest times to diversify the medium- and long-term income. Teak can be planted in combination with one or several tree species with different growth cycles:

  - Slow-growing species to diversify timber production: mahogany (*Swietenia macrophylla*), sonokeling (*Dalbergia latifolia*),
  - Fast-growing species to provide medium-term income: sengon, gmelina,
  - Species that produce fruits and vegetables to earn monthly or yearly short-term income: mango (*Mangiefera indica*), durian (*Durio zibethinus*), petai (*Parkia speciosa*), melinjo (*Gnetum gnemon*), candlenut (*Aleurites moluccana*),
  - Species that produce fodder and fuel wood: tayuman (*Bauhinia purpurea*), lamtoro (*Leucaena leucocephalai*), caliandra (*Caliandra calothyrsus*), gliriside (*Gliricidia sepium*), or
  - Tree species that produce other nontimber products: sandalwood (*Santalum album*).
- The species composition should also be based on the canopy height and the root characters. It can help maintain and improve land and environmental quality. For example:
  - Species that enrich the soil: Leguminosae including lamtoro and sesban tree,
  - Species with deep roots to prevent erosion: candlenut, petai and mahogany, or
  - Avoid species that require a great amount of water: pine.
- In addition to the species variation, if the teak plantation serves as a way to save money for unexpected needs, varying the planting time allows for selective harvesting later.

5.2. Land preparation

How can we prepare the land for teak planting?

Land preparation includes the following activities: site selection, clearing land of bushes and weed roots, stump destruction, ploughing, harrowing, and stone removal.

Table 5.1 Suitability of tree species and site (elevation and rainfall)

Elevation (m asl)	Dry season (rainfall < 2000 mm/yr)	Rainy season (rainfall > 2000 mm/yr)
Lowland (< 350)	akor, Australian pine, avocado, banyan, bayur, candlenut, coconut, durian, gliricidia, gmelina, guava, gutta percha, hantap, huru, jackfruit, jatropha, johar, kapok, kedaung, keppel, keranji, lamtoro, mahogany, mang, matoa, mindi, neem, orange, papaya, rain tree, rambutan, salak, sesban tree, sonokeling, soursop, suren, tayuman/kupu-kupu, tisuk/ waru gunung	akor, banyan, breadfruit, bungur, candlenut, durian, gmelina, gutta percha, hantap, huru, jackfruit, jatropha, kadam, kihiang, mahogany, mangium, mindi, papaya, rain tree, salak, saninten, sengon, sesban tree, soursop, sungkai, suren, tamarind, ulin
Moderate land (350 – 700)	african wood, akor, avocado, aren, banyan, Barbados nut, breadfruit, candlenut, cashew nut, durian, gliricidia, gmelina, guava, gutta percha, hantap, huru, jackfruit, johar, kapok, kedaung, kedondong, keranji, lamtoro, longan, mahogany, mango, mindi, neem, orange, papaya, picung, pine, rain tree, rambutan, rasamala, red calliandra, salak, sesban tree, sonokeling, soursop, suren, tisuk	akor, avocado, banana, banyan, breadfruit, bungur, candlenut, cempedak, chrysolite, cloves, cocoa, coconut, coffee (robusta), duku, durian, gmelina, guava, gutta percha, hantap, huru, jackfruit, jambu air, jatropha, jengkol, kadam, kedondong, kihiang, longan, mahogany, mangium, mangosteen, melinjo, mindi, oil palm, orange, papaya, petai, pine, pomegranate, rain tree, rambutan, rasamala, red calliandra, resins, rubber, salak, saninten, sapodilla, sengon, sesban tree, tamarind, soursop, starfruit, sugar apple, sungkai, suren, ulin

Elevation (m asl)	Dry season (rainfall < 2000 mm/yr)	Rainy season (rainfall > 2000 mm/yr)
Highland (> 700)	african wood, apple, aren, avocado, banyan, breadfruit, candlenut, coconut, coffee (arabica), gliricidia, gmelina, hantap, huru, guava, gutta percha, jackfruit, jatropha, johar, kapok, kedondong, keranji, kesambi, lamtoro, longan, mahogany, mangleid, mango, mindi, orange, papaya, picung, pine, pineapple, rain tree, rasamala, red calliandra, soursop, suren, terap, tisuk, weru	avocado, banyan, breadfruit, bungur, candlenut, cloves, coffee (arabica), gmelina, gutta percha, hantap, huru, jackfruit, jambu air, jambu biji, jatropha, kadam, kedondong, kesambi, kihiang, longan, mahogany, mindi, orange, papaya, persimmon, pine, quinine, rain tree, rasamala, red calliandra, resins, saninten, sapodilla, sengon, soursop, sugar apple, suren, tamarind, tea, weru

Sources: Agency for Agricultural Research and Development (2006), Mindawati *et al*. (2006), Soerianegara and Lemmens (1994), Roshetko (2001)

Why is land preparation necessary?

Land preparation is necessary to provide the best growing conditions possible for teak. Land clearing and tillage are done to reduce weeds and improve soil quality. Land clearing also reduces shade, since teak is a shade-intolerant species.

How to choose suitable land for teak

Teak grows naturally in lowland areas from 0 to 1000 m asl with rainfall of 1250–3000 mm annually, and with regosol-grumosol soil types. However, to produce high-quality timber, choose sites that also:

- have soils with high lime and clay content,
- have distinct dry and rainy seasons,
- are located less than 700 m asl.

Can we cultivate on rocky and sloping land?

- Sloping land is vulnerable to landslides and erosion so teak needs terraces.
- Build terrace walls with stones.
- On rocky land monocultures or mixed plantations are more appropriate than agroforestry systems, because tillage for annual crop production is difficult.

Figure 5.4 Teak growing on terraced land

5.3. Planting

What activities are required before planting?

Preparation before planting includes:

- Arranging the space,
- Preparing and installing markers, and
- Preparing planting holes.

What spacing is right for teak?

- In a monoculture system, the most commonly used spacings are 2.5×2.5 m, 3×1 m, 2×3 m and 3×3 m.
- Dense spacing will produce straighter stems and faster height growth, whereas wide spacing will produce larger stem diameters.

Figure 5.5 Teak plantation with regular spacing

- A good combination is dense spacing in the early stages in order to promote height growth, then thinning to promote larger stem diameter.
- In an agroforestry system, teak can be closely spaced within their rows with a wider distance between rows for planting seasonal crops such as cassava, corn, patchouli, peanut or soybean.

Why should the planting distance be uniform?

Consistent spacing offers several advantages. For example, it:

- Makes maintenance easy. The plantation will look good and clean.
- Makes the best use of space for trees to maximise growth of canopy, stem and roots.
- Reduces competition between trees for moisture and nutrients from the soil allowing the tree to maximise growth.
- Reduces competition between trees for light and improves air circulation, allowing the stem and canopy to grow healthy.
- Reduces the potential of tree damage due to strong wind.

What if uniform spacing is not possible?

Where the land is rocky or the soil layer is thin, uniform spacing of your planting may be too difficult. These conditions also make it difficult for seedlings to survive, so:

- Use irregular spacing.
- Plant seedlings with dense spacing (minimum 1 m), on land where the

Figure 5.6 On rocky land, regular spacing may be difficult to achieve

soil layer allows seedlings to grow. This requires a minimum soil depth of 20 cm.

- When the trees are about 3–5 years old, densely planted trees will require thinning to reduce competition. Select trees for thinning that have poor form or slow growth. Reduce spacing to a minimum of 2 m.
- Thinning is discussed in detail in Section 6.

What is an appropriate size for a planting hole?

- The planting hole should be 30×30×30 cm.
- On rocky land, you can reduce the width of the planting hole to 10–20 cm.
- At each planting hole, place a marker made from bamboo or wood to indicate the location of the planting hole.

What techniques are used in teak planting?

- Smallholder teak plantations can be generated by maintaining and selecting the teak that generates naturally on the site.
- In addition, teak plantations can also be established through artificial regeneration; teak seeds or seedlings are intentionally planted at specific spacings.
- With artificial regeneration, there are several possible techniques: by direct sowing of seeds called '*cemplongan*' in which prepared soil and seeds are placed in the planting hole; or by planting seedlings from wildings or from seed.

What is the *cemplongan* system?

- Dig a planting hole (*cemplong*) using a sharp stake or handspike.
- Place 2–3 teak seeds in each planting hole to increase the likelihood that at least 1 seedling will grow in each planting hole.

- If more than one seedling grows in a hole, wait one year, including one dry season, then select the seedling with the best growth to be retained. Remove the other seedling or transplant it to a hole where no seedlings survived.

What is the best way to plant seedlings?

- If the nursery is far from the planting site, seedlings may dry out from exposure or lack of water during travel.
- In such cases, seedlings should not be planted immediately.
- Maintain seedlings near the planting site for 1 week; this allows them to adapt to the planting environment and recover from dessication.
- Plant seedlings in the rainy season or when rainfall has made the soil moist.
- Before planting, apply to each planting hole a basic fertiliser of 10 kg compost (derived from leaves) or manure (derived from cattle waste).
- Make sure that the manure used is completely composted and not harmful to the seedlings.
- Seedlings can be planted 2–4 weeks after you apply the fertiliser.
- Remove the seedlings from the polybag carefully to keep the medium undamaged.
- Place the seedlings into the planting hole, and backfill it with topsoil or humus. Place soil from the bottom layer to the upper portion of the planting hole.
- Compact the soil by holding the seedling by the stem and slowly tamping down the soil around the seedlings with your feet.
- Place the seedling bag at the end of the marker, as a sign that the seedling has been planted and to demonstrate that the polybag has been removed.

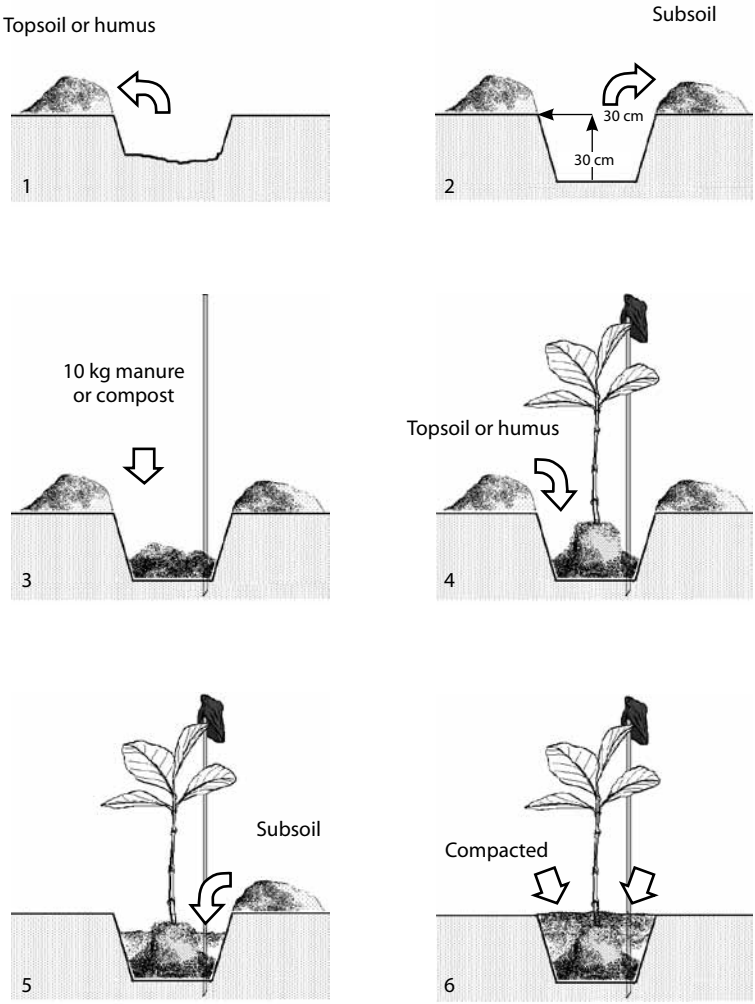


Figure 5.7 Seedling planting technique

6

Maintaining teak stands

What activities are part of teak stand maintenance?

Teak grows well, grows fast, and produces high-quality timber when the land and trees and well maintained. Maintenance includes weeding, fertilising, replanting, pruning, thinning, maintaining coppices and controlling pests and diseases.

6.1. Weeding

Should the understorey, shrubs or grass around the teak be cleared?

- Yes, it is necessary. In a young teak plantation weeds including vines, shrubs and grass need to be cleared regularly around teak trees. These weeds compete for light, water and soil nutrients. Left uncontrolled, the weeds could hinder the growth and even kill the teak trees.
- In a mature teak plantation after the canopy closes, weeding can be done less frequently. Understorey weeds below mature trees generally die by themselves.
- You can effectively control weeds by intercropping teak trees with agricultural crops, because tilling for the crops also serves as weeding for the trees.

6.2. Fertilising

Do trees need fertiliser?

Applying fertiliser when the trees reach 1, 2 and 3 years in age is recommended.

- The recommended dose per tree is 50 g of NPK in the first year, 100 g in the second year and 150 g in the third year.
- Apply manure or compost at a dose of 10 kg per planting hole before planting the tree.
- On acidic soils, soils with a low pH or soils with limited calcium (Ca), the area around the trees should be treated with lime (dolomite) to raise the pH.
- The recommended dose of dolomite is 150–250 g per planting hole, applied at the same time as the manure or compost.
- In agroforestry systems, applying fertiliser benefits both teak trees and agricultural crops.
- To apply fertiliser make holes with a small wooden stake on either side of the tree or crop.
- Another way is to apply fertiliser in holes 10-15 cm deep that ring the teak tree at a distance of 0.5–1.5 m from the stem, about the width of the tree's canopy.

6.3. Infilling

What is infilling and why do we need to do it?

- Infilling is the replacement of dead plants with new seedlings.
- Infilling maintains the intended spacing or density of teak trees in the plantation.

- Infilling is also useful for replacing broken, unhealthy or poorly growing plants.
- Infilling should be done in the rainy season.

6.4. Pruning

Why is pruning necessary?

- Pruning is the removal of branches which increases clear bole height and reduces knots on the main stem.
- By removing unnecessary branches or twigs, the tree's growth will concentrate around the tree's main stem and its canopy.
- Wood removed through pruning can be used as fuelwood or sold at market, providing smallholders with added revenue.
- Pruning can reduce the damage done by forest fires because the separation of the tree crown slows the spread of fire between trees.

How to prune

- Pruning commences in the third year.
- Clear branches and twigs from the lower half of the tree. Pruning more than 50% can hinder the tree's growth.
- Prune early in the rainy season, around August.
- Prune when branches and twigs are still young and small.

Figure 6.1 Pole pruners and pole saw used to prune branches

- Prune each branch as close to the main stem as possible, without cutting the branch collar. The branch collar is the slight swelling at the base of the branch where it grows from the stem. Pruning the branch collar causes wounds that heal more slowly and also increases the risk of pests and diseases.
- If pruning is delayed, the removal of large branches will result in knot defects in the wood; pruning large branches also makes the tree more susceptible to pests and diseases.
- Pruning is done using special tools: pruners and pruning saws. Small, young twigs can be pruned with a sharp sickle or machete.
- To protect the stem after pruning, cover each pruned place with a special paint or tar.

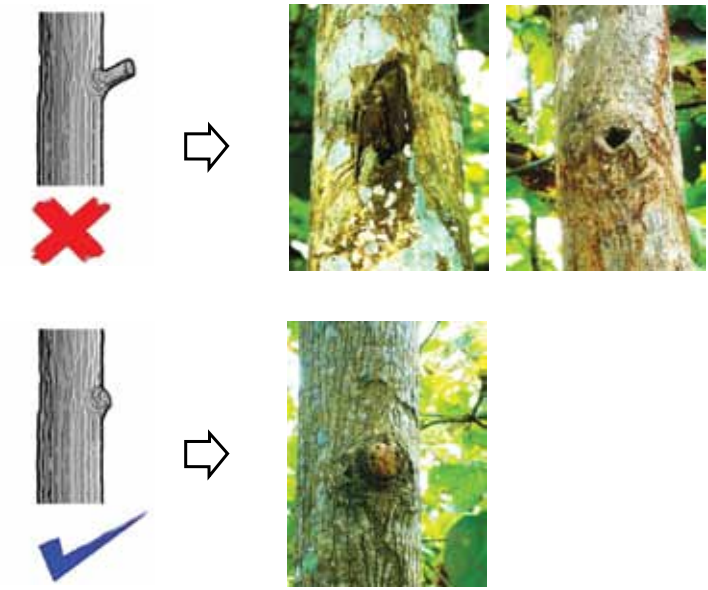


Figure 6.2 Effect of pruning on stem quality

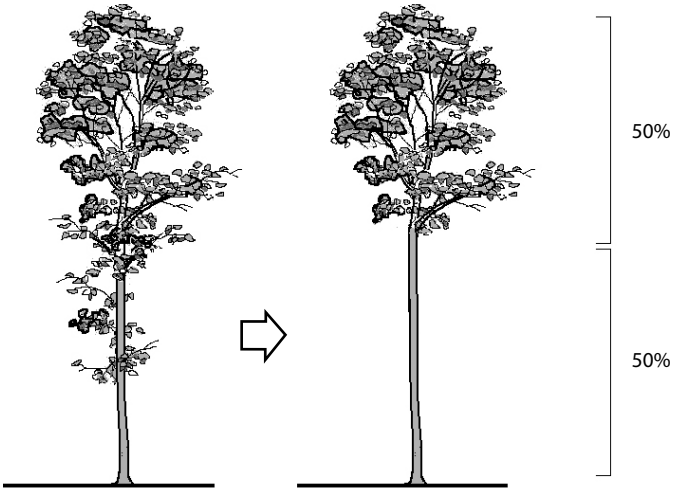


Figure 6.3 Recommended height to which branches should be pruned

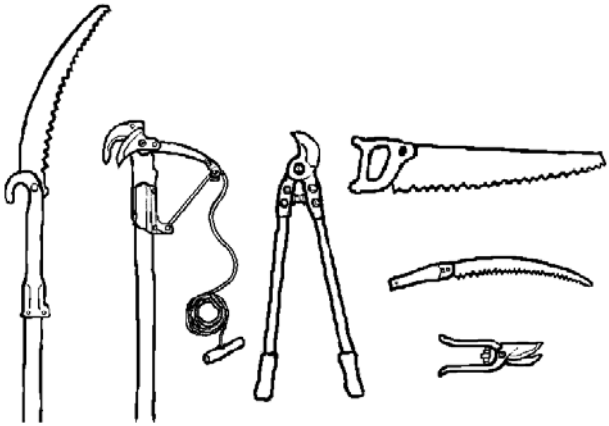


Figure 6.4 Equipment suitable for pruning

6.5. Thinning

Why are plantations thinned?

- Competition for light, water and nutrients is greater in closely spaced plantations causing slower tree growth and tall, skinny stems.
- The removal of stressed, unhealthy and slow-growing trees will encourage better growth for the good quality trees that remain. (Good quality trees are fast-growing and healthy and have good stem form.)
- Thinning helps maximise tree growth, prevent the spread of disease and distribute trees more evenly.
- The trees harvested during thinning can be sold to raise income. Any harvested trees with diameters greater than 10 cm can be used for construction timber while the smaller ones are suitable for firewood.

How can we best thin trees?

- In monoculture teak stands, thin every 3–5 years until the trees reach the age of 15. Thinning should be conducted more frequently if only a few trees are cut per thinning.
- After most trees in the stand reach the age of 15 years, thin every 5–10 years.
- Select trees for thinning that are diseased, otherwise defective, slow-growing, stressed or have poor form. Poor form means the timber will be worth less at market.
- In understocked plantations, teak trees with poor stem form do not require thinning to maximise growth of the remaining trees, because competition is low. However, according to the experience of farmers in Gunungkidul, harvesting those trees will produce coppice growth that will generate trees with straight stems.

Figure 6.5 Regularly spaced trees after thinning

- The number of trees left after thinning can be based on the height of the trees, which is influenced by age and site fertility (site index).
- According to the thinning table from Perum Perhutani (Table 6.1), when average tree height is 13.5–15.5 m, the number of trees after thinning should be 1000–1100 trees/ha. On fertile land, this can be achieved in 7 years, while on the low quality site it may require 17 years.

Table 6.1 Trees left after thinning based on tree height

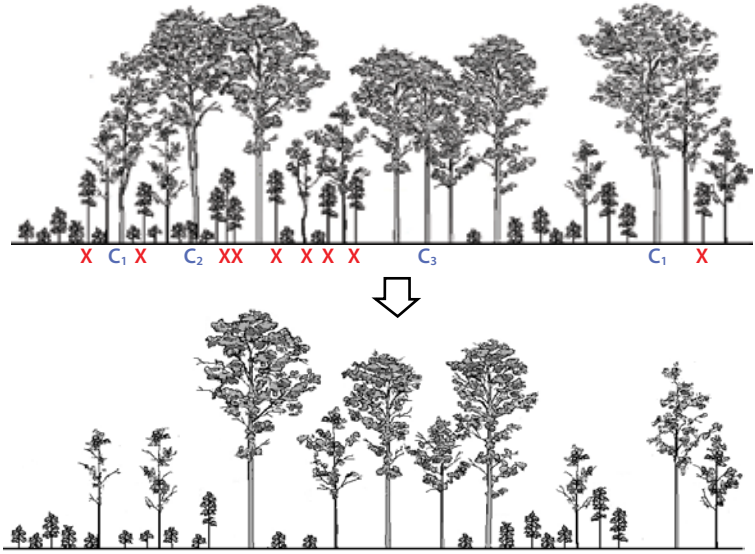
Tree height (m)	Trees remaining (trees/ha)	Age (yr) (range based on soil fertility)	Spacing (m)
11.0–13.0	1300–1500	5–11	2.5–3.0
13.5–15.5	1000–1100	7–17	3.0
15.5–17.0	800–850	10–21	3.5
17.5–21.0	500–550	15–34	4.0–4.5

Source: Based on the Perum Perhutani thinning table (Perhutani 2001)

How to thin unevenly aged teak trees

- In a monoculture system with evenly aged and regularly spaced stands, thinning is relatively easy to perform. Slow-growing or depressed trees will be easily distinguished from the average and from fast-growing trees of the same age.
- For unevenly aged and irregularly spaced teak stands, thinning is more difficult. Here is some general guidance.
    a. Focus on each tree. If one tree is cut, how will that affect the surrounding trees? If the tree is not cut, how will that affect the surrounding trees?
    b. If the canopies are overlapping, it indicates that the stand should be thinned.
    c. Cut the trees growing under the tree canopy (which do not get sufficient light), diseased trees and those with poor stem quality.
    d. Trees do not require thinning if only the bottom section of the canopy is in shade.
    e. Seedlings or young trees growing in an open area should be retained to grow.
    f. To maintain the diversity of tree size and age, for varied harvesting times, the remaining trees in the stand after thinning should still represent various ages and diameter classes.
- Thinning to improve the quality of the remaining trees can also remove large, saleable trees. This is known as commercial thinning.
- Thinning teak plantations can be planned and conducted to promote savings. When funds are needed, smallholders can perform commercial thinnings to harvest trees for market sale that will increase the value of the remaining trees at the same time.

- Perform a commercial thinning to remove large trees:
  a. to promote optimal and even growth of the remaining trees,
  b. to open the canopy to allow smaller trees access to more light to grow faster and healthier, or
  c. to increase the spacing between stems.



Description:

X = Non-commercial thinning

C = Commercial thinning

C1 = Trees thinned to open canopy, allowing growth of new trees

C2 = Trees thinned this way will cause canopy of surrounding trees to develop faster

C3 = Less densely spaced trees

Figure 6.6 An example of thinning in an unevenly aged teak stand

6.6. Coppice maintenance

How to manage teak coppice

- After teak trees are harvested, the remaining stumps will produce coppices that can be managed to produce healthy trees.
- Early growth from a coppice is usually faster than early growth from seed, allowing for quick re-establishment of a teak plantation.

Figure 6.7 Management of teak coppice from a harvested tree
a) Young coppice, b) One shoot left to grow becoming mature tree

- However, because the coppice roots often develop only on one side of the tree , the trees may be less resistant to wind than trees from seed.
- Trees from coppice are also vulnerable to rot originating from the stump and more often develop hollow stems at the base.
- To improve root system development and reduce the possibility of hollow stems, cut the stumps as close to the ground as possible.

Cut them close during timber harvest or afterwards when you prepare to re-establish the plantation.

- Usually multiple coppices will grow from each stump and will need thinning.
- Retain the healthiest, largest and straightest coppice and thin the rest. If possible, retain the coppice that starts low on the stump.
- Because coppice growth will continue to develop, thin periodically to encourage growth of the selected coppice.

Figure 6.8 Coppice from stump

6.7. Controlling pests and diseases

What pests frequently attack teak plantations?

Pests commonly found in teak include:

1. The tree termite *Neotermes tectonae*, called *inger-inger*. They cause swelling on the trunk and branches. *Inger-inger* can infest teak trees when they are as young as 3 years. But the infestation is visible only later, when trees are 7 years old.

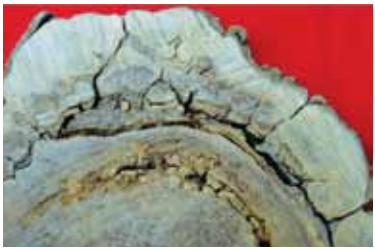


Figure 6.9 Wood damage caused by *inger-inger* (*Neotermes tectonae*)

Figure 6.10 ***Ulan-ulan*** **and the damage it causes**

2. The stem borer *Monohammus rusticator*, called *ulan-ulan*. This pest can cause swelling of stems and holes in stems, often resulting in broken stems.
3. The wood bore *Xyleborus destruens* bores transverse holes in the stem. Bore holes from this insect have black stains around the hole edge, which can be seen by peeling the bark. This insect commonly attacks teak that are 5 years old or older.
4. *Pyrausta machaeralis*, *Eutectona machaerallis* and *Hyblaea puera* are caterpillars that commonly eat teak leaves.
5. *Holotrichia helleri* and *Lepidiota stigma* are pupae, or *uret*, that attack the roots of teak seedlings and young trees between 1 and 2 years old. Trees wither and eventually die because of the root damage.

Figure 6.11. Attack by wetwood borer causes deep holes in wood

How to control *inger-inger*

- Prevent the spread of *inger-inger* attacks by thinning regularly.
- Remove infected trees before the beginning of the rainy season when *inger-inger* begin to emerge.
- Cut and burn the infected parts of trees.
- Chemical control to kill *inger-inger* is accomplished with fumigant insecticides (phostoxin ¼ tablet) or insecticides containing fenpropatrin (Meothrin 50 EC).

How to control stem borer

- Stem borers can be controlled with a fumigant insecticide of phostoxin, injected to the infected stem through bored holes.

How to control wetwood borer

- To avoid wetwood borer attack, teak should not be planted in areas without clear distinction between rainy and dry seasons.
- Wherever wetwood borer has attacked, that area should no longer be planted with teak.
- Clear weeds from around the bases of trees to reduce microclimate humidity and foster a habitat unfavourable to the wetwood borer.
- Insecticides used to eliminate the wetwood borer include Brash 25 EC, Lentrek 400 EC, Dragnet 380 EC, Enborer 100 EC and Cislin 2.5 EC.

How to control caterpillar

- Gunungkidul farmers report that caterpillar (*Hyblaea puera*) attack is not harmful to teak. Infestations only last about 1 week. When teak caterpillars become pupae they fall naturally from the tree. Farmers usually collect them in the morning hours for eating or selling.
- Measures taken to control teak caterpillars should not adversely affect the understorey, which provides habitat for birds and other predators of teak caterpillar.
- When caterpillar attacks are severe, use an insecticide containing the active ingrediants deltamethrin (Decis 2.5 EC), permethrin (Ambush 2 EC) or LAMDA sihalotrien (Matador 25 EC).

How to control *uret*

Anggraeni and Asmaliah (2007) report several ways of controlling *uret* infestations.

- Larvae can be collected during soil tillage and then destroyed, or beetles are caught at night by luring them with a bright light.
- Apply various insecticides in the planting hole before or during planting.
- Common insecticides contain the active ingredients carbosulfan (Marshal 5G), carbofuran (Curaterr 3G, Furadan 3G, 3G and Indofuran Petrofur), etoprofos (Rhocap 10G) and diazinon (Diazinon 10G). Apply at recommended rates available where chemicals are sold.
- Traditionally, farmers in Gunungkidul eradicate *uret* using grated yam, jambe fruit skins or mahogany seeds which are crushed, mixed and scattered around the planting hole or over the whole area to be planted.

Figure 6.12 Teak seedling infected with wilt

What diseases are common problems for teak?

- The bacterium *Pseudomonas tectonae* causes wilt. This disease usually attacks teak seedlings or young teak trees. Early symptoms are the presence of light and dark brown patches, followed by leaf wilt and leaves turning pale or yellowish. The development of wilt may be gradual or sudden with leaves falling in a short period of time.
- The fungus *Phoma* sp causes shoot disease. This disease usually occurs in young teak. Leaves are infected as they develop, resulting in dead leaves and shoots. Shoot disease results in irregular growth and deformed, crooked trees.
- The fungus *Corticium salmonicolor* causes *upas*. This fungal diseases occurs frequently and spreads quickly during the rainy season. The visible symptoms are discoloured, black, limp, withered leaves that seem scalded. Thick layers of fruiting bodies develop on the bark, with bumps on the stems. Wounds and cracks appear on the trunk.
- *Nectria haematococca* causes stem cancer. Symptoms are wilted leaves and the formation of dark black bumps on the surface of the stem. These bumps erupt and fissured, elongated wounds develop into holes in the trunk.

How to control wilt

- When the occurrence of wilt is minor, use a bactericide containing an active compound of streptomycin sulfate (Agrept 20 WP), dazomet (Basamid G), and oksolinik acid (Starner 20 WP).
- If you can see wilt symptoms on seedlings, destroy the seedlings immediately by burning.

Figure 6.13 Teak stem and leaves infected with *upas* fungal disease

- Do not intercrop young teak trees with crops of the Solanaceae family (including aubergine, potato, tomato and chili), because those species can host wilt.

How to control dead shoot disease

Rahayu (1999) reports that dead shoot disease can be controlled this way.

- Remove infected shoots during the rainy season to avoid spreading the disease.
- Humidity within the plantation is reduced by pruning tree branches to increase airflow and sunlight .
- Apply fertiliser to stimulate plant growth and form of new shoots.

How to control fungal, or *upas*, disease

Fungal disease can be controlled this way.

- Remove *Lantana* sp. plants from near teak plantings because they are a source of fungal disease.
- Space teak trees regularly according to size or age of the tree.
- Maintain and prune regularly.
- Apply fungicide containing the active compound karbendazim (Derosal 60 WP) to control a fungal breakout.

How to control stem cancer

- Stem cancer can be prevented and controlled in this way.
- Host plants such as *Lantana* sp. should be cleared from land near teak plantations. *Lantana* sp. includes kembang telek, tembelekan or tahi ayam.
- Space the trees to allow adequate light exposure and good air circulation.
- Prune regularly.
- If infection occurrs, eradicate the disease by scraping the wounded stem and then smear it with kooltir, TB 192, fungicide of Fylomac 0.5% or Antimuci 0.5% every three weeks.

7
Harvesting

When should teak be harvested?

To provide maximum returns, harvest teak trees when:

- the tree is mature enough to produce good quality wood, at least 15–20 years old;
- The price for teak timber is high.

How to measure wood volume

- The volume of standing trees can be calculated using teak volume tables, which depend on the quality of the site where the teak is planted. See a sample volume table for teak in Appendix 2.
- Measure the diameter of the stem at breast height, called DBH. The standard for DBH is 130 cm.
- Timber stem volume is calculated by multiplying the average basal area at the base and the top of the tree or log by its length:

$$\left\{ \textit{Stem volume} = \frac{\left(\frac{3.14 * Db^2}{4}\right) + \left(\frac{3.14 * Dt^2}{4}\right)}{2} * L \right\}$$

Where: Db = diameter at base
Dt = diameter at top
L = length of log

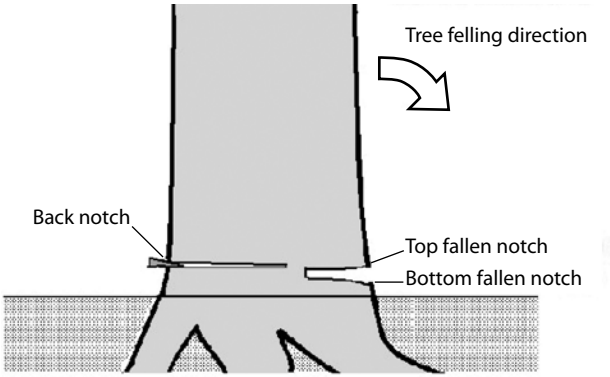


Figure 7.1 Fallen notch and back notch

How to harvest teak trees

Teak trees should not be harvested by cutting on only one side to prevent breaking or damaging the high-value stem.

- First, determine the direction that minimizes potential damage to the tree being harvested and other trees.
- Before harvesting the tree, remove branches and twigs.
- Cut notches on two sides, then lower the stem to the ground in the direction it is falling.
- One side of the trunk is sawed parallel with the felling direction; that cut is called the fallen notch. The distance between the base and the upper part of the notch should be a maximum of 5 cm.
- The opposite side of the stem is then sawed up to the upper part of the notch; that cut is called the back notch (See Figure 7.1).

Is it best to harvest all the trees at once or only some of them?

There are two main harvesting methods for smallholder teak plantations.

- In the clear-cut system all trees in a particular area are felled. This is usually done in a plantation of evenly aged teak (Figure 7.2).

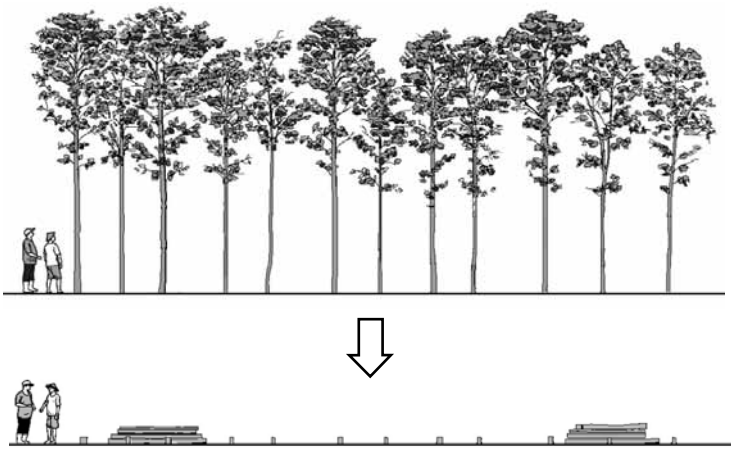


Figure 7.2 Clear-cut harvesting

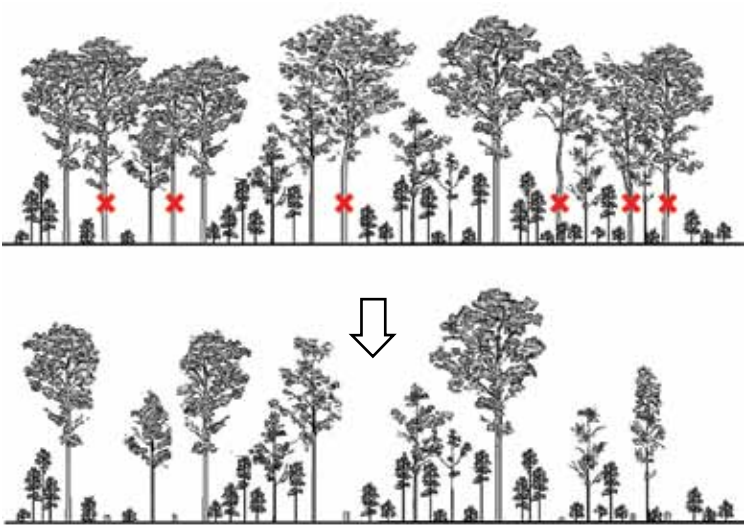


Figure 7.3 Selective harvesting

- In the selective harvesting system, trees are selected according to the need. This method is generally used in unevenly aged teak stands, or mixed plantations. This system is also practised for commercial thinning (see thinning in unevenly aged forest in Section 6.5 and Figure 7.3).

8
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List of species

Local names (Indonesia)	Common names	Scientific names
Akor	Akor	*Acacia auriculiformis*
Alpokat	Avocado	*Persea americana*
Bayur	Bayur	*Pterospermum javanicum*
Beringin	Banyan	*Ficus benyamina*
Bungur	Bungur	*Lagertromia speciosa*
Cemara Laut	Australian pine	*Casuarina equisetifolia*
Damar	Damar	*Agathis loranthifolia*
Durian	Durian	*Durio zibethinus*
Gadung	Gadung	*Dioscorea hispida*
Gamal	Gliricida	*Gliricidia sepium*
Gmelina	Gmelina	*Gmelina arborea*
Hantap	Hantap	*Sterculia urselta*
Huru	Huru	*Litsea* sp
Jabon	Kadam	*Anthocephalus sinensis*
Jambu biji	Guava	*Psidium guajava*
Jarak pagar	Jatropha	*Jatropha curcas*
Jeruk Bali	Pomelo	*Citrus maxima*
Johar	Johar	*Cassia siamea*
Kedaung	Kedaung	*Parkia roxburghi*
Kemiri	Candlenut	*Aleurites moluccana*
Kelapa	Coconut	*Cocos nucifera*
Kepel	Keppel	*Stelechocarpus burahol*
Keranji	Keranji	*Pongamia pinnata*
Kihiang	Kihiang	*Albizia procera*

Local names (Indonesia)	Common names	Scientific names
Kaliandra	Red calliandra	*Calliandra calothyrsus*
Kayu Afrika	African wood	*Maesopsis eminii*
Kesambi	Kesambi	*Schleichera oleosa*
Lamtoro	Lamtoro	*Leucaena leucocephala*
Mahoni	Mahogany	*Swietenia macrophylla*
Mangga	Mango	*Mangifera indica*
Mangium	Mangium	*Acacia mangium*
Matoa	Matoa	*Pometia pinnata*
Mimba	Neem	*Azadirachta indica*
Mindi	Mindi	*Melia azedarach*
Nanas	Pineapple	*Ananas comosus*
Nangka	Jackfruit	*Artocarpus heterophyllus*
Pepaya	Papaya	*Carica papaya*
Pinus	Pine	*Pinus merkusii*
Pulai	Gutta percha	*Alstonia scholaris*
Rambutan	Rambutan	*Nephelium lappaceum*
Randu	Kapok	*Ceiba petandra*
Rasamala	Rasamala	*Altingia excelsa*
Salak	Salak	*Salacca zalacca*
Saninten	Saninten	*Castanea argentea*
Sengon	Sengon	*Paraserianthes falcataria*
Sirsak	Soursop	*Annona muricata*
Sonokeling	Sonokeling	*Dalbergia latifolia*
Srikaya	Sugar apple	*Annona squamosa*
Sungkai	Sungkai	*Peronema canescen*
Suren	Suren	*Toona sinensis*

Local names (Indonesia)	**Common names**	**Scientific names**
Tayuman	Tayuman	*Bauhinia purpurea*
Temu ireng	Temu ireng	*Curcuma aeruginosa Roxb.*
Tisuk/Waru Gunung	Tisuk/Waru Gunung	*Hibiscus macrophyllus*
Trembesi	Rain tree	*Albizia saman*
Turi	Sesban tree	*Sesbania grandiflora*
Ulin	Ulin	*Eusideroxylon zwageri*
Weru	Weru	*Albizia procera*

Glossary

Certified seed: Seed collected from certified seed sources that verify the seed's genetic origin.

Clear bole: The main stem of a tree from the ground to the first branch; the main stem of a tree that is branchless.

Clones: A group of plants that are genetically identical, as they result from a vegetative propagation (through cutting, grafting, or tissue culture) coming from a single tree trunk.

Closely related: Seed or trees that have a close family relationship. Seeds from one tree are closely related.

Compost: Fertiliser from decomposition of plant material, including litter, harvested leaves or vegetable waste.

Coppice: Shoots or stems growing from the base of a tree or stump after harvesting a tree.

Crown: The top segment of a tree including branches, twigs and leaves.

Cutting: A technique for vegetatively propagating plants in which one part of a plant –shoot, stem, leaf, root – is planted, produces new roots, leaves or stems to become a new plant; cuttings may be treated with hormones (see Indole butyric acid) to encourage the growth of roots or stems.

Diameter: The distance across a circle through its centre point. Tree stem diameter can be determined by measuring the circumference (girth) of the stem and then divided by 3.14.

Disease: An organism such as bacteria, viruses or fungi that harms or damages a plant.

Dolomite limestone: Limestone that includes magnesium ions and in which calcium is replaced by magnesium. It is usually found in limestone hills and is used in fertilisers.

Ecological: The relationships between living organisms and their environments.

Generative: Parts of the plant that contribute to reproduction through pollination, including the flower, fruit and seed.

Genetics: The branch of biology that deals with heredity; the characteristics of an individual encoded in DNA and inherited from parents.

Grafting: A technique to combine parts from two different plants to form a new plant. This technique requires a scion, an upper plant part such as a stem, branch or leaf, and a root stock, a lower plant part. Scions should come from superior plants. Root stocks should be suited to local environmental conditions and resistant to pest and disease.

Grumusol: A type of soil with high clay content (more than 30%), high swelling and shrinkage. Grumusol is often referred to as vertisol or margali. Soil experts can help farmers identify soil types.

Indole butyric acid: IBA, is a plant hormone that regulates growth. It belongs to the group of hormones called auxins. IBA is widely used to stimulate growth in roots and shoots during vegetative propagation.

Litter: Dead organic material from plants, including leaf fragments, twigs, fruit stalks, petals and weed seeds.

Manure: Animal waste, used to produce organic fertiliser.

Paranet: A common type of shading net.

Pest: Any species of animal that can damage trees and forest species including insects, squirrels, rats and wild pigs. Most pests that affect trees are insects.

Porous medium: A substance with enough air spaces so liquids can easily penetrate, without breaking down the medium. Porous media include coconut coir husks, rice husks and compost mixed with soil.

Pre-treatment: Any treatment applied to seeds before sowing, to hasten and improve seed germination.

Regosol: A type of soil that is grey in colour and fertile. It is also called inceptisol, alluvial soil, andosol or gleihumus. Soil experts can help farmers identify soil types.

Scarification: Cracking or cutting the hard outer seed coat so water can be absorbed by the seed and improve and accelerate germination. Scarification can be done manually, mechanically, chemically or naturally.

Seed tree: High-quality trees selected and maintained to produce seeds.

Self-pollination: Pollination of a flower by pollen from the same tree or clone.

Shading net: A light net that protects plants from heat and direct sunlight. It is usually made from plastic and available in different thicknesses for use in different degrees of shade.

Sowing medium: A substance in which to germinate seeds and produce germinants.

Stump: The part of the plant that remains once all leaves, root branches, root hairs and most of the stem has been removed; a stump includes a small part of the stem and main root.

Superior seed: Seeds with unmarred physical appearance, free of dirt. Physically superior seeds are undamaged; physiologically superior seeds have high germination and viability rates; and genetically superior seeds produce uniform stands of tree that are faster growing than common seeds.

Terracing: Grading of sloping land to create level areas to prevent erosion and landslide and improve growing.

Tissue culture: Propagation technique using tissues or organs from a plant growing in a special sterile media. This technique can produce large numbers of clones, up to thousands, with the same traits as the parent.

Transplanting: Uprooting a plant to replant it in another location.

Vegetative: Leaves, stems, shoots and roots of a plant.

Water content: The proportion of water in seeds, wood or soil. The percentage of water in any material is based on the weight before and after drying the material.

Weed: Any unwanted plants that interfere or damage the growth of cultivated plants.

Appendices

Appendix 1. Names and addresses of farmers in Gunungkidul District, Yogyakarta, involved in testing the practicality of the manual

1 Adi Suwito, Giripanggung Village
2 Adijulan, Karangduwet Village
3 Adiyanto, Bejiharjo Village
4 Agus Susila, Bejiharjo Village
5 Ahmadi, Bejiharjo Village
6 Badarudin, Girisekar Village
7 Bakat, Karangduwet Village
8 Citro W, Bejiharjo Village
9 Dartasujono, Sumber Village
10 Dwi, Bejiharjo Village
11 Edi Sudarni, Girisekar Village
12 Giyono Saputro, Bejiharjo Village
13 Giyono, Dadapayu Village
14 Hadi Sularno, Giripanggung Village
15 Hadiwinoto, Dadapayu Village
16 Hardi Subroto, Jeruklegi Village
17 Harjo Suwarno, Giripanggung Village
18 Harno Suwito, Kepuhsari Village
19 Harso Suyono, Candirejo Village
20 Heri Suyatno, Giripanggung Village
21 Heri, Katongan Village
22 Istadi, Bejiharjo Village
23 Jamiyo, Kepuhsari Village
24 Joko Narwanto, Sumber Village
25 Jumirin, Karangduwet Village
26 Jumiya, Bejiharjo Village
27 Karsino, Kedungkeris Village
28 Kismarejo, Candirejo Village
29 Kisno Sakiran, Bejiharjo Village
30 Krida Suyarno, Sumber Village
31 Kuwadi, Karangduwet Village
32 Lina Juarti, Kepuhsari Village
33 Mardi Wiyono, Bejiharjo Village
34 Margiyo, Girisekar Village
35 Margiyono, Katongan Village
36 Margono, Bejiharjo Village
37 Margono, Giripurwo Village
38 Marjono, Candirejo Village
39 Markan, Dadapayu Village
40 Matsi, Dadapayu Village
41 Medi Suminarno, Girisekar Village
42 Murjiyanti, Bejiharjo Village
43 N. Basrudin, Bejiharjo Village
44 Ngatino, Bejiharjo Village
45 Purwitoyo, Dadapayu Village
46 Puryadi, Bejiharjo Village

47 Ratijo, Giripurwo Village
48 Ruhiyem, Kepuhsari Village
49 Sagiyo, Bejiharjo Village
50 Sahirin, Giripurwo Village
51 Samta, Katongan Village
52 Santhoso, Karangduwet Village
53 Saryono, Karangduwet Village
54 Sri Daryanti, Bejiharjo Village
55 Sudardiyanto, Bejiharjo Village
56 Sugito, Dadapayu Village
57 Sugito, Kedungkeris Village
58 Sugiyanto, Giripurwo Village
59 Suhani, Bejiharjo Village
60 Sukimin, Dengok Village
61 Sukiyardi, Karangduwet Village
62 Sulistiyono, Bejiharjo Village
63 Sumadi, Giripanggung Village
64 Sumanto, Bejiharjo Village
65 Sumino, Jeruklegi Village
66 Sumiran, Karangduwet Village
67 Sumirdjo, Karangduwet Village
68 Sumirdjo, Karangduwet Village
69 Sunarya, Karangduwet Village
70 Sunarya, Karangduwet Village
71 Sungkono, Giripanggung Village
72 Supardi, Girisekar Village
73 Suparman, Giripurwo Village
74 Suparmin S, Sumber Village
75 Suparmin, Giripurwo Village
76 Suparto, Dadapayu Village
77 Supoyo, Giripanggung Village
78 Supriyanto, Dengok Village
79 Suradal, Kedungkeris Village
80 Suradi, Bejiharjo Village
81 Suranto, Katongan Village
82 Suroyo, Dadapayu Village
83 Sutarno, Bejiharjo Village
84 Suwandi, Giripanggung Village
85 Suwito, Bejiharjo Village
86 Tukijan, Giripurwo Village
87 Tukirin, Dadapayu Village
88 Viftin Agustina, Dadapayu Village
89 Wadirin, Dengok Village
90 Wagiya, Kedungkeris Village
91 Wagiyono, Bejiharjo Village
92 Wahyudi, Katongan Village
93 Warijan, Giripanggung Village
94 Wasiran, Giripurwo Village
95 Widiyanto, Dengok Village
96 Wuhono Hs, Kedungkeris Village

Appendix 2. Example of tables for estimating standing volume

SITE QUALITY I

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	5.842	5.7912	1.280	0	0.256	0.0000	5.0970	5.0970
20	9.398	8.5344	669	0	0.314	0.0000	12.4594	12.4594
30	12.446	9.7536	435	0	0.365	0.0000	18.8307	18.8307
40	14.986	10.668	332	0.014	0.376	0.8495	23.5030	24.3525
50	17.526	11.5824	262	0.043	0.352	3.1149	25.7683	28.8832
60	19.812	12.192	220	0.086	0.315	7.0792	26.0515	33.1307
70	21.844	12.8016	192	0.125	0.272	11.6099	25.2020	36.8119
80	23.876	13.716	170	0.157	0.225	16.4238	23.5030	39.9268
90	25.654	14.0208	158	0.192	0.197	21.2376	21.8040	43.0416
100	27.178	14.6304	141	0.215	0.169	25.7683	20.2465	46.0149
110	28.448	15.24	133	0.229	0.147	29.4495	18.9723	48.4218

SITE QUALITY I / II

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	6.35	6.7056	1.114	0	0.239	0.0000	5.6634	5.6634
20	10.16	9.4488	584	0	0.307	0.0000	13.7337	13.7337
30	13.208	11.5824	393	0	0.345	0.0000	21.5208	21.5208
40	16.002	12.8016	296	0.022	0.361	1.6990	27.4673	29.1664
50	18.796	14.3256	231	0.062	0.324	5.6634	29.7327	35.3961
60	21.082	14.9352	197	0.110	0.287	11.3267	29.4495	40.7763
70	23.622	15.8496	165	0.160	0.239	18.4060	27.4673	45.8733
80	25.654	16.4592	147	0.196	0.201	24.6357	25.2020	49.8377
90	27.432	17.3736	135	0.220	0.165	30.5822	22.9366	53.5188
100	29.21	17.9832	125	0.241	0.137	36.2456	20.5297	56.7753
110	30.988	18.5928	115	0.257	0.113	41.3426	18.1228	59.4654

SITE QUALITY II

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	7.112	8.5344	911	0	0.275	0.0000	8.4951	8.4951
20	11.176	11.8872	483	0	0.317	0.0000	17.8396	17.8396
30	14.732	14.3256	322	0.007	0.334	0.5663	26.1931	26.7594
40	17.78	15.8496	243	0.044	0.328	4.2475	31.4317	35.6792
50	20.32	16.764	201	0.094	0.303	10.1941	32.9891	43.1832
60	23.114	17.6784	166	0.152	0.251	18.6891	30.8654	49.5545
70	25.654	18.8976	142	0.196	0.2	27.1842	27.7505	54.9347
80	27.94	19.812	124	0.229	0.156	35.3961	24.0693	59.4654
90	29.972	20.4216	116	0.256	0.126	42.7584	21.0961	63.8545
100	32.004	21.336	105	0.275	0.104	49.5545	18.6891	68.2436
110	33.782	21.9456	98	0.285	0.089	55.2179	17.2733	72.4911

SITE QUALITY II / III

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	8.382	10.0584	673	0	0.356	0.0000	13.3089	13.3089
20	12.7	14.3256	381	0	0.356	0.0000	24.6357	24.6357
30	16.51	16.4592	260	0.028	0.353	2.5485	32.4228	34.9713
40	20.066	18.288	194	0.088	0.307	9.9109	34.4050	44.3159
50	23.114	19.812	159	0.150	0.247	19.8218	32.7060	52.5278
60	25.908	20.7264	136	0.201	0.196	29.7327	29.0248	58.7575
70	28.702	21.9456	116	0.243	0.15	40.2099	24.7772	64.9872
80	31.242	22.86	104	0.271	0.114	49.5545	20.8129	70.3674
90	33.528	23.7744	94	0.295	0.092	58.0495	18.1228	76.1723
100	36.068	24.6888	85	0.303	0.78	64.5624	16.7069	81.2693
110	38.608	25.908	76	0.304	0.068	70.2258	15.7158	85.9416

SITE QUALITY III

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	9.144	11.2776	580	0	0.346	0.0000	14.8663	14.8663
20	14.224	15.8496	310	0.011	0.372	0.8495	29.0248	29.8743
30	18.796	18.5928	208	0.063	0.324	6.7960	34.6881	41.4842
40	22.86	20.7264	154	0.147	0.254	19.2555	33.2723	52.5278
50	26.416	22.2504	125	0.211	0.189	32.2812	28.8832	61.1644
60	29.972	23.7744	104	0.263	0.134	45.8733	23.3614	69.2347
70	33.02	24.9936	91	0.295	0.098	57.4832	19.1139	76.5971
80	35.814	26.2128	81	0.309	0.081	66.2614	17.4149	83.6763
90	38.608	27.1272	73	0.319	0.071	73.9070	16.5654	90.4723
100	41.148	28.3464	67	0.320	0.063	80.9862	15.8574	96.8436
110	43.688	29.5656	62	0.319	0.056	87.4991	15.2911	102.7902

SITE QUALITY III / IV

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	10.414	13.1064	469	0	0.376	0.0000	19.6802	19.6802
20	16.51	17.9832	243	0.027	0.366	2.5485	34.2634	36.8119
30	21.844	21.0312	161	0.125	0.273	15.8574	34.6881	50.5456
40	26.67	23.1648	120	0.217	0.186	33.6970	28.8832	62.5802
50	30.988	25.2984	96	0.280	0.119	51.2535	21.8040	73.0575
60	35.052	26.8224	80	0.314	0.088	64.8456	18.2644	83.1099
70	38.608	28.0416	69	0.334	0.075	75.6060	16.9901	92.5961
80	41.91	29.2608	62	0.339	0.065	84.6674	16.1406	100.8080
90	44.958	30.48	56	0.343	0.057	93.1624	15.5743	108.7367
100	48.006	31.6992	52	0.341	0.05	101.3743	14.8663	116.2407
110	50.8	32.9184	48	0.340	0.045	109.3030	14.3000	123.6030

SITE QUALITY IV

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	12.192	14.3256	374	0	0.394	0.0000	24.6357	24.6357
20	19.304	20.1168	184	0.077	0.334	8.7782	38.0862	46.8644
30	25.4	23.7744	128	0.2	0.213	30.8654	32.9891	63.8545
40	30.734	26.2128	98	0.280	0.122	53.2357	23.2198	76.4555
50	35.56	28.0416	79	0.320	0.088	69.9426	19.2555	89.1981
60	39.878	29.5656	66	0.342	0.072	83.5347	17.5564	101.0911
70	44.196	31.0896	58	0.349	0.06	95.7109	16.4238	112.1347
80	48.006	32.6136	51	0.353	0.052	107.0377	15.7158	122.7535
90	51.562	33.8328	46	0.359	0.046	117.2317	15.0079	132.2397
100	55.118	35.3568	42	0.354	0.04	126.5763	14.4416	141.0179
110	58.166	36.576	40	0.351	0.037	134.7882	14.0168	148.8050

SITE QUALITY IV / V

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	14.478	16.4592	299	0.1	0.426	0.8495	34.5466	35.3961
20	21.844	22.2504	116	0.131	0.286	18.1228	39.6436	57.7664
30	28.448	25.908	113	0.248	0.156	45.8733	28.8832	74.7565
40	34.544	28.3464	84	0.310	0.092	69.3763	20.6713	90.0476
50	39.878	30.48	68	0.339	0.071	88.3486	18.5475	106.8961
60	45.212	32.6136	57	0.354	0.058	105.0555	17.2733	122.3288
70	50.038	34.4424	49	0.361	0.049	120.0634	16.2822	136.3456
80	54.61	35.9664	44	0.365	0.042	134.2219	15.4327	149.6545
90	58.42	37.1856	40	0.368	0.037	146.3981	14.8663	161.2644
100	62.23	38.7096	36	0.369	0.034	157.7248	14.4416	172.1664
110	65.786	39.9288	34	0.364	0.03	167.6357	14.0168	181.6526

SITE QUALITY V

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	16.51	17.9832	243	0.033	0.44	3.1149	41.2010	44.3159
20	24.13	24.384	146	0.174	0.234	28.3168	38.0862	66.4030
30	31.496	28.0416	99	0.282	0.114	60.8812	24.6357	85.5169
40	38.354	31.0896	73	0.325	0.075	85.5169	19.6802	105.1971
50	44.45	33.528	59	0.345	0.058	106.4713	17.8396	124.3110
60	50.292	35.6616	50	0.356	0.048	124.8773	16.7069	141.5842
70	55.372	37.4904	44	0.358	0.04	141.0179	15.8574	156.8753
80	60.452	39.0144	39	0.360	0.035	155.4595	15.0079	170.4674
90	65.024	40.5384	35	0.361	0.031	168.7684	14.5832	183.3516
100	69.342	41.7576	32	0.360	0.028	180.3783	14.0168	194.3952
110	73.152	43.2816	30	0.540	0.025	190.8555	13.7337	204.5892

SITE QUALITY V / VI

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	17.78	19.812	221	0.05	0.378	5.3802	41.0594	46.4396
20	26.162	26.2128	130	0.203	0.191	37.0951	34.8297	71.9248
30	34.29	30.48	88	0.285	0.091	70.2258	22.5119	92.7377
40	41.402	33.528	66	0.324	0.063	96.8436	18.6891	115.5327
50	48.006	36.2712	53	0.339	0.048	118.9308	16.9901	135.9209
60	54.356	38.7096	45	0.344	0.04	138.7525	15.9990	154.7516
70	60.198	40.2336	39	0.354	0.035	156.3090	15.2911	171.6001
80	65.278	42.0624	35	0.354	0.03	172.7328	14.5832	187.3159
90	70.612	43.2816	31	0.355	0.027	185.7585	14.1584	199.9169
100	75.184	44.8056	28	0.350	0.024	197.9348	13.7337	211.6684
110	78.994	46.3296	27	0.344	0.022	208.9783	13.5921	222.5704

SITE QUALITY VI

Age (yr)	Mean Diameter (cm)	Mean Height (m)	Stand density (trees/ (ha)	Stem form factor of large tree	Stem form factor of small tree	Total volume of large tree (m^3)	Total volume of small tree (m^3)	Total volume of large & small trees (m^3)
10	19.05	21.0312	202	0.07	0.334	8.4951	40.4931	48.9881
20	27.686	28.0416	122	0.222	0.159	45.5901	32.7060	78.2961
30	36.322	32.6136	81	0.294	0.077	80.1367	20.9545	101.0911
40	44.704	35.9664	59	0.321	0.053	107.3208	17.6980	125.0189
50	51.816	38.7096	48	0.335	0.042	129.9743	16.2822	146.2565
60	58.166	40.8432	41	0.341	0.035	150.0793	15.4327	165.5120
70	64.262	42.9768	35	0.344	0.03	168.7684	14.7248	183.4932
80	70.104	45.1104	31	0.343	0.026	185.1922	14.3000	199.4922
90	75.692	46.6344	28	0.341	0.024	199.6338	13.8753	213.5090
100	80.772	48.1584	26	0.337	0.021	212.6595	13.4505	226.1100
110	85.09	49.3776	24	0.335	0.02	224.5526	13.1673	237.7199

Source: Champion, H.G. 1934. Von Wülfing's Yield Tables for Teak Plantation in Java. Forest Bulletin No 87. Delhi: Manager of Publications.

The typical practice by smallholder teak growers of letting trees grow without management input has resulted in poor quality plantations. Various questions arise when farmers start to better manage their teak plantations. This book provides practical guidance in addressing these questions by explaining in detail the techniques of parent tree selection, seed preparation, seedling production, planting, fertilising, thinning, pruning, controlling pest and disease and harvesting. To be more easily understood, the descriptions are complemented by illustrations, photographs or tables.

This manual is somewhat different from other teak silvicultural manuals because it is written in simple language, specifically designed for smallholder teak farmers. Specific problems faced in managing teak plantations are often not addressed in existing manuals. How to plant teak on rocky land, how to thin trees in uneven-aged stands, how to maintain coppices from stumps, and how to harvest trees with a need-based cutting system are addressed. Some techniques discussed are adopted from farmers' traditional knowledge in Gunungkidul.

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