PART 7

PLANTING TREES

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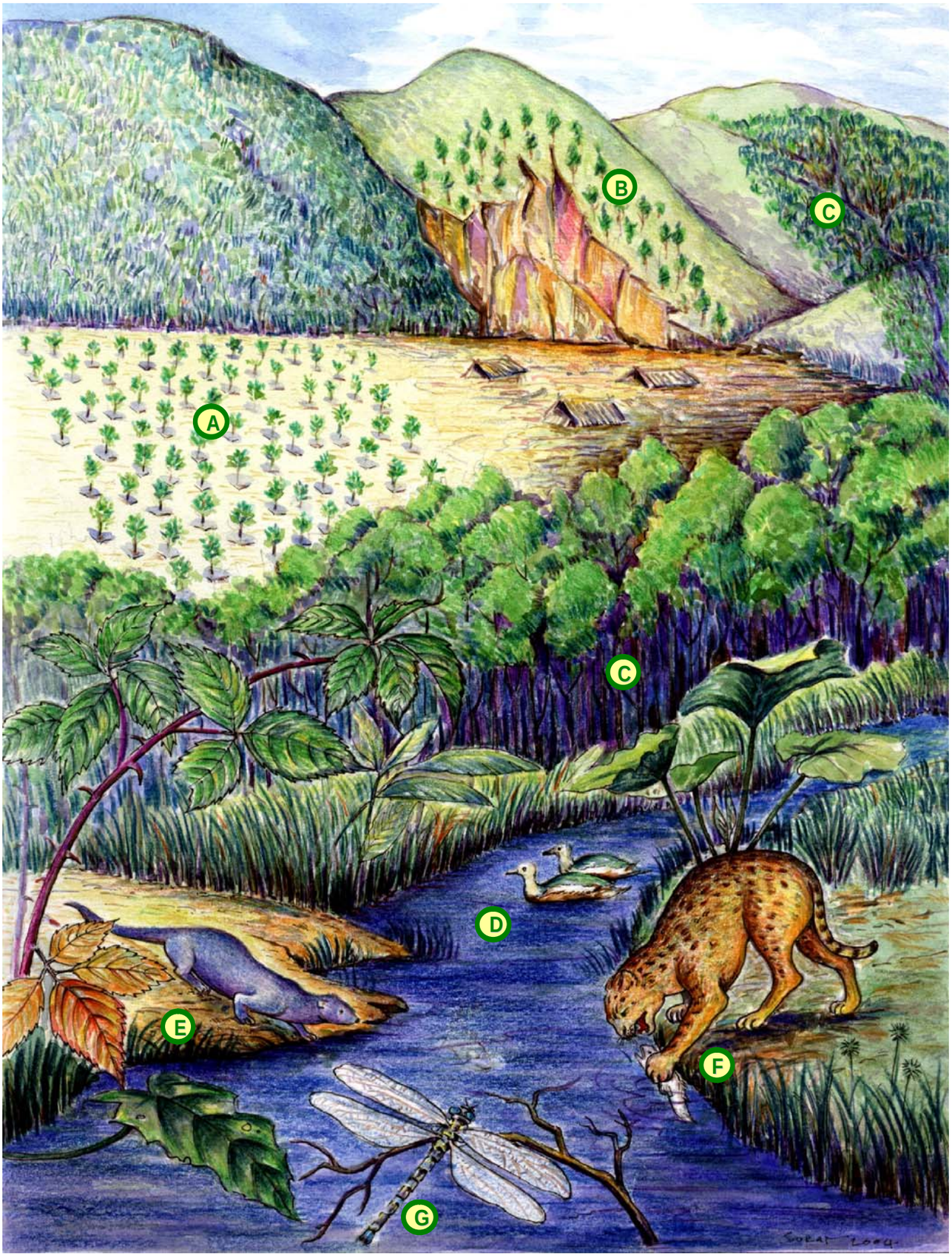
SELECTING A SITE
PREPARING TO PLANT
THE PLANTING EVENT
CARING FOR PLANTED TREES
MONITORING FOREST RECOVERY

"Give fools their gold and knaves their power,
Let fortunes bubbles rise and fall.
Who sows a field, or trains a flower,
Or plants a tree is more than all."
- John Greenleaf Whittier (1807-92),
U.S. poet. "A Song of Harvest"

Planting Sites to Maximize Conservation Value



For maximum conservation value, plant framework tree species (A) to link forest patches by creating wildlife corridors; (B) to create permanent forest wherever the risk of soil erosion or landslides is high and (C) to protect water courses, essential to the survival of specialised wildlife such as White-winged Wood-duck (D), otters (E), Fishing Cat (F) and dragonflies (G).

PLANTING TREES

"He who plants a tree is the servant of God,
He provides a kindness for many generations,
And people he will never see shall bless him."
Henry van Dyke (1852-1933), U.S. poet. "The friendly trees"

Tree planting is undoubtedly one of the most popular activities of forest restoration. At the end of a hard day's work, the sight of degraded land, dotted with newly planted saplings, is immensely rewarding and gives planters the satisfaction of knowing they have done what they can to reverse the destruction of natural resources. However, tree planting is by no means the end of the forest restoration process: long term commitment is essential for success. Whilst it may be easy to mobilize a community for tree planting events, it is often more difficult to maintain motivation to care for the trees after planting. Unless weeds are controlled, fertilizer applied and fires prevented, the hard work of the tree planters and the immense effort expended in the nursery to grow the planted trees may amount to nothing. Forest restoration is a process, not just a tree planting event. Therefore, this Part provides an overview of all those activities that are necessary to ensure the success of forest restoration projects, after the trees have left the nursery.

SECTION 1 – SELECTING A SITE

Where should framework trees be planted?

As already explained in Part 5, the framework species method of forest restoration is especially suitable for conservation areas – national parks, wildlife sanctuaries, nature reserves and so on – where biodiversity conservation is a high management priority (although it can also provide forest products where economic benefits are needed). Although cost-effective in the long-term, the method requires a considerable investment of time, labour and money to begin with (see Part 8). Consequently, it makes sense to first select priority sites, where tree planting will yield maximum benefits for ecological integrity, biodiversity conservation and environmental protection.

Such sites include:

- Wildlife corridors to reverse forest fragmentation
- Sites around springs and along stream sides
- Sites at risk of soil erosion and landslides

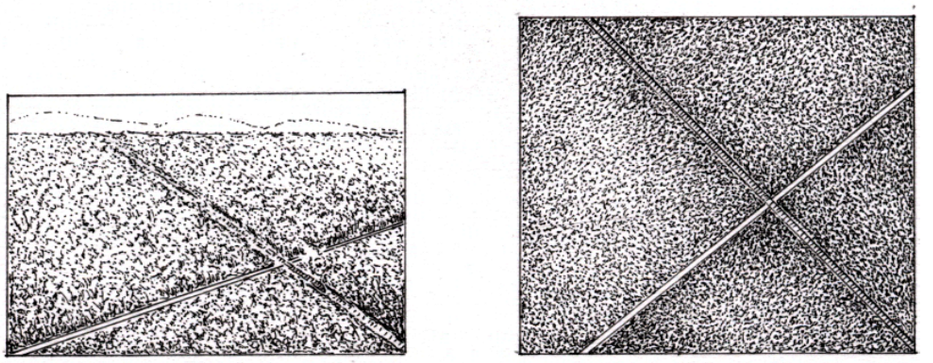
What is forest fragmentation?

Forest fragmentation is when large, continuous areas of forest become dissected by roads, other infrastructure, cultivated land and so on. The small, disconnected forest patches created, then shrink due to further disturbances (*e.g.* chopping, burning *etc.*) eroding them from their edges inwards. Small, isolated populations of plants and animals, living in such tiny forest fragments, are at high risk of extirpation, through inbreeding, diseases and vulnerability to catastrophes (*e.g.* fires) that would not usually threaten the survival of larger populations in larger forest areas. Genetic isolation also increases the risk of extirpation.

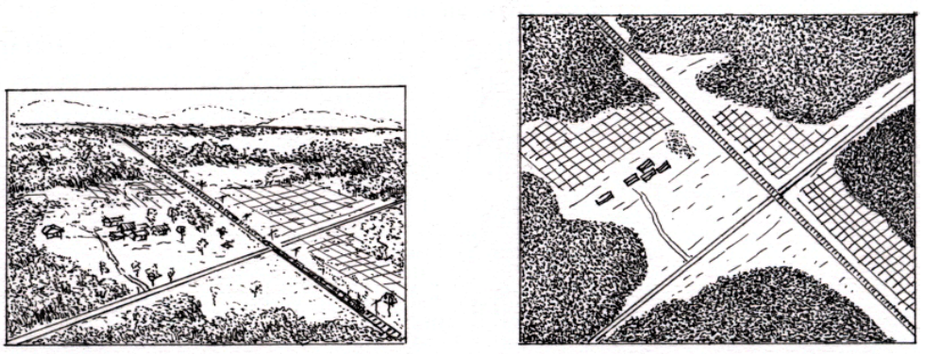
Once a species population within a forest fragment becomes extirpated, re-colonization by migration of founder individuals from other forest areas becomes difficult or impossible, due to inhospitable terrain (*e.g.* agricultural or urban development) between fragments. Few forest animal species migrate across large non-forested areas (except some bats and birds). Consequently, large animal-dispersed seeds are rarely transported between forest fragments.

Four Stages of Forest Fragmentation

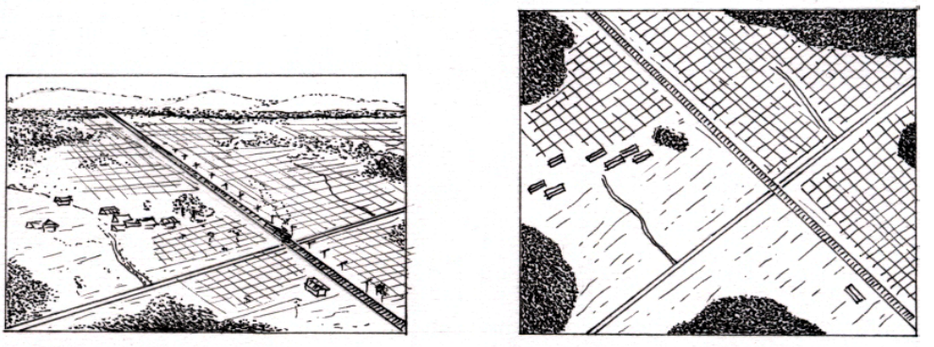
DISSECTION
Roads, railways, power lines etc. cut into a large expanse of forest.



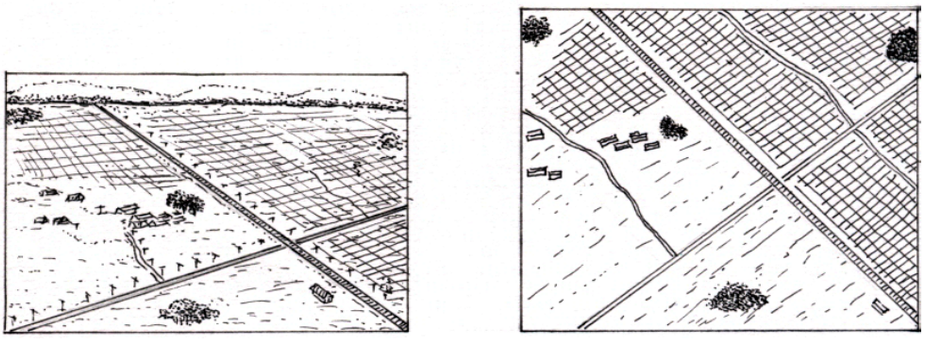
PERFORATION
Holes develop in the forest as settlers exploit the land along the lines of communication.



FRAGMENTATION
The gaps become larger than remaining forest.



ATTRITION
Isolated forest remnants are gradually eroded by edge effects.



Tiny forest fragments can support only very small populations of animals, which are highly vulnerable to extirpation. Once gone, species cannot return, since migration between forest patches is hindered by vast areas of agricultural land or dangerous barriers such as roads. Planting wildlife corridors to re-link forest fragments can overcome some of these problems and help create viable wildlife populations in a fragmented landscape.

What is a wildlife corridor?

Reconnecting small forest fragments to larger forest areas, by planting framework tree species to form "wildlife corridors", can reverse the damaging effects of fragmentation. Such corridors can provide wild animals with the security needed to migrate from one forest patch to another. Genetic mixing recommences and, if a species population becomes extirpated from one forest patch, it can be re-founded by immigration of individuals from another forest patch along the corridor. Wildlife corridors can also help re-establish natural routes followed by migratory species. However, they are only effective where hunting does not occur or can be efficiently prevented. Otherwise wildlife corridors become shooting galleries – drawing wildlife out from the safety of conservation areas and exposing them to danger.

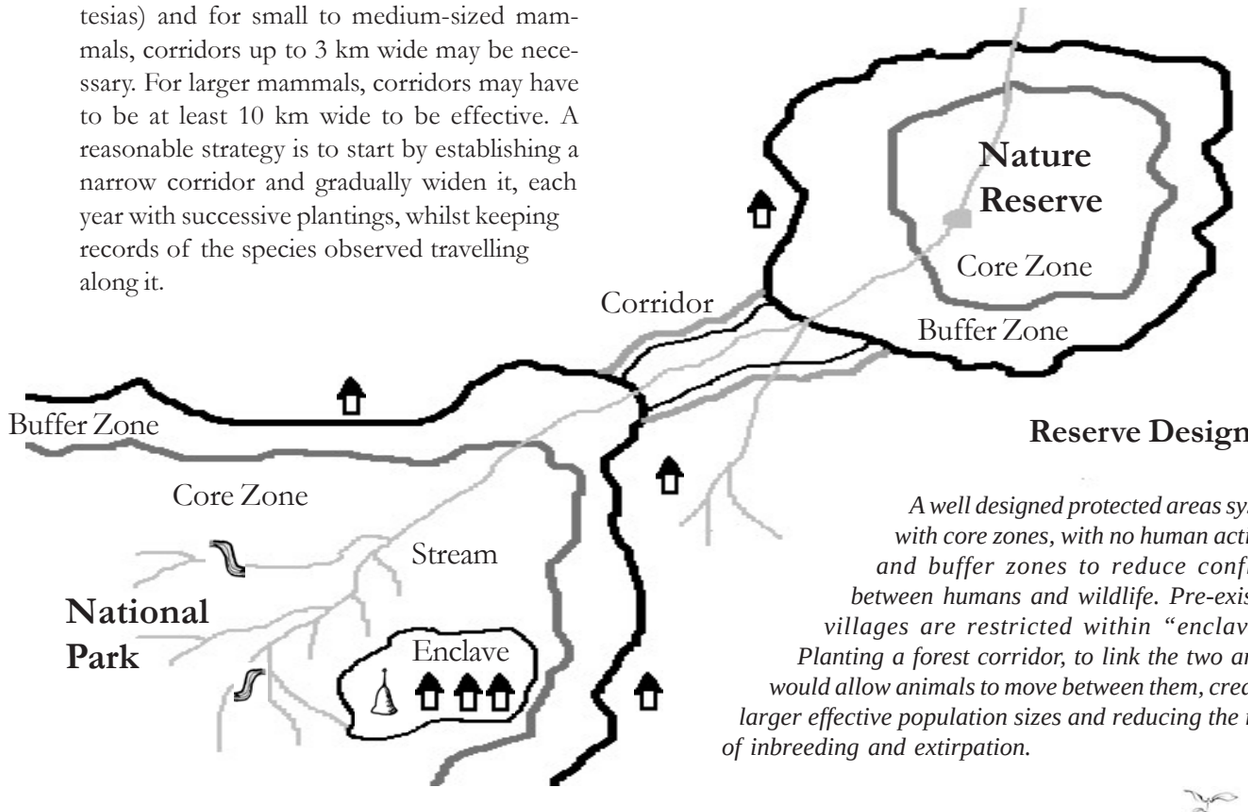
How wide should a corridor be?

This depends on the animals likely to use it. For insects and some small bird species, a line of trees a few metres wide may be sufficient to allow them to move from one forest fragment to another. For birds of the forest floor and undergrowth, however, (e.g. babblers or tesias) and for small to medium-sized mammals, corridors up to 3 km wide may be necessary. For larger mammals, corridors may have to be at least 10 km wide to be effective. A reasonable strategy is to start by establishing a narrow corridor and gradually widen it, each year with successive plantings, whilst keeping records of the species observed travelling along it.

Can tree planting protect water courses?

Yes. Tree planting in upper watersheds, particularly around springs, can help improve the regularity of water supplies and water quality. Although trees do remove water from the soil, by transpiration through their leaves, they more than make up for it by adding organic matter to the soil through leaf litter production. Over time, organic matter increases the water-holding capacity of the soil, so that it can absorb more water during the rainy season and release it during the dry season. In this way, forest restoration can convert seasonally-dry streams into permanently flowing ones.

Planting along stream banks creates riparian habitats that are essential for those specialized species (from dragonflies to otters), which live in or beside sheltered streams. Such habitats also serve as essential refuges for many other, not so specialized, animal species during the dry season, when neighbouring habitats dry out or burn. Riparian tree-planting also prevent stream bank erosion and the clogging of stream channels with silt. This reduces the risk of streams bursting their banks during monsoon deluges, resulting in flash floods.



Reserve Design

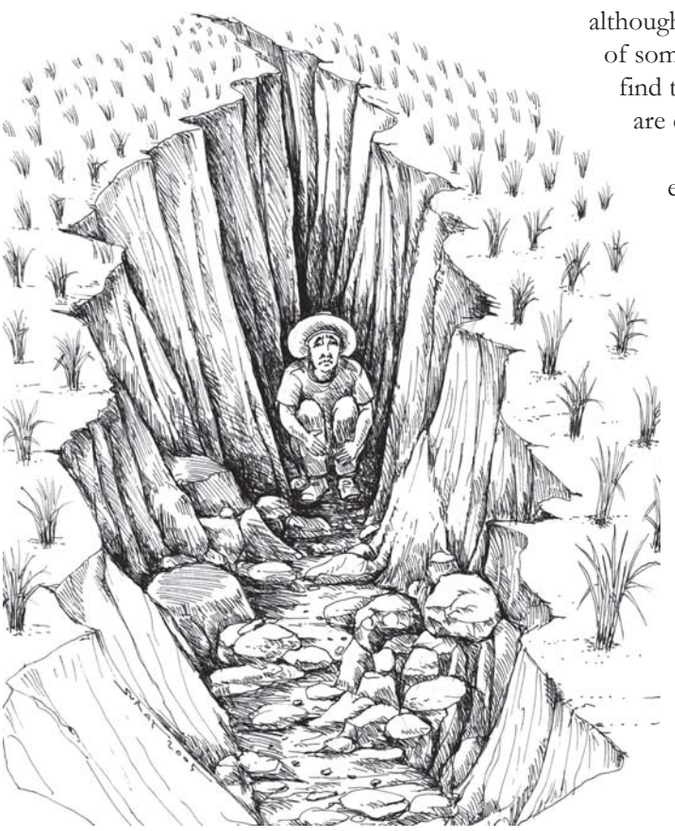
A well designed protected areas system with core zones, with no human activity, and buffer zones to reduce conflicts between humans and wildlife. Pre-existing villages are restricted within "enclaves". Planting a forest corridor, to link the two areas, would allow animals to move between them, creating larger effective population sizes and reducing the risks of inbreeding and extirpation.

Can tree planting reduce soil erosion and landslides?

Yes. Soil erosion reduces the capacity of a water catchment to store water, leading to floods in the rainy season and droughts in the dry season. Deposition of eroded soil in river channels adds to the risk of flooding. Landslides are an extreme form of soil erosion. They can occur with such suddeness and force that they can compeltely detroy villages, infrastructure and agricultural land and kill many people. Mountainous sites with long, steep, uninterrupted slopes are particularly at risk from soil erosion and landslides.

Tree planting can help reduce the risks of both gradual soil erosion and sudden landslides, because tree roots bind the soil, preventing movement of soil particles. Leaf litter helps to improve soil structure and drainage. It increases the penetration of rainwater into the soil (infiltration) and reduces surface runoff.

Gulley erosion can devastate agricultural land and lead to rural poverty. Forest restoration can help prevent both gulley erosion and landslides.



Most countries have a national watershed classification system, with maps showing the relative risk of soil erosion in any particular site. Ask your local agricultural extension service to consult such maps to determine the extent to which tree planting might help reduce erosion in your locality.

Should framework tree species be planted on other sites?

In many circumstances, sites that both i) match the criteria discussed above and ii) are available for forest restoration, may not be present. This may be due to social and legal constraints, including land tenure issues, the need for agricultural land and lack of accessibility. So, is it worth carrying out forest restoration on sites with lower conservation value than those described above?

The answer is "probably yes". Even sites, which are distant from existing forest, can still be planted with framework tree species to good effect. Biodiversity recovery in such sites may occur more slowly and not proceed as far as in sites closer to intact forest. However, more mobile wildlife, such as birds and bats may colonise isolated forest restoration plantings, although large mammals and the largest seeds of some climax forest tree species may never find their way back to such sites unless they are deliberately re-introduced.

One of the main advantages of establishing isolated forest restoration plantings is that they act as "nuclei", from which natural forest regeneration can spread across degraded landscapes, as their seeds are gradually dispersed out into neighbouring areas. They also provide a seed source for future forest restoration tree nurseries in the vicinity.

However, isolated forest restoration plantings are particularly vulnerable to edge effects and the other problems described above for forest fragments, so intensive management is necessary to prevent such problems.

Box 7.1 - Forest Landscape Restoration

What is it?

When planning forest restoration, it is important to consider planting sites as one of many components of the wider landscape, having ecological and socio-economic interactions with agricultural land, natural forest, plantations, water courses, villages, infrastructure and so on.

The World Wide Fund for Nature (WWF) and IUCN-The World Conservation Union have proposed 'Forest Landscape Restoration' (FLR), as an all-encompassing, landscape management concept that aims to "regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes". With the participation of *all* stake-holders, FLR combines several existing development, conservation and natural resource management principles to restore both the quality and quantity of forest, in degraded forest landscapes, to benefit both people and nature.

A "landscape" is defined as a contiguous area of land, intermediate in size between a "site" and an "ecoregion", with distinct ecological and socio-economic characteristics, which distinguish it from neighbouring "landscapes". A forest landscape is defined as "degraded" when, because of forest loss or degradation, it is no longer able to maintain an adequate supply of forest products or ecological services for human well-being, ecosystem functioning and biodiversity conservation.

To conserve biodiversity, FLR recognizes the need to protect and manage remaining forest. Preventing forest fragmentation is seen as critically important to maintain biodiversity. However, FLR acknowledges that forest protection measures, in isolation, will not completely prevent further forest fragmentation and biodiversity loss. Forest restoration is, therefore, acknowledged as an important component of FLR, but one which must provide benefits to people, as well as to wildlife.

In short, FLR is designed to integrate biodiversity conservation with local people's livelihoods at the landscape level. Communities play a critical role in shaping the landscape and, together with wildlife, they must gain significant benefits from forest resources, to provide the necessary motivation to encourage them to take an active role in forest conservation and restoration.

What can it achieve?

By working closely with local communities, through consultation, training and information exchange, FLR should:

- Restore environmental functions – including water, biodiversity and soil stability – by tree planting, ANR or natural regeneration.
- Provide utilitarian benefits to local communities, including forest products, clean water and flood prevention.
- Protect biodiversity and the health of nearby forests.
- Balance land-use trade-offs at the landscape level.
- Keep future land-use options open.
- Adapt to changes in land-use and ecosystem dynamics.
- Reverse the threat of further deforestation.

FORRU-CMU as an example

FORRU's work with local communities provides an excellent example of FLR in practise. In the multipurpose landscape, surrounding the village of Mae Sa Mai, in Doi Suthep-Pui National Park, FORRU-CMU is working with the community to restore forest in the upper watershed to:

- Restore natural forest ecosystems for wildlife conservation.
- Regulate water supplies and water quality, thus contributing to the needs of both the Mae Sa Mai community and downstream communities.
- Provide attractions and stimulus for development of an ecotourism business at Ban Mae Sa Mai and thus generate income.
- Provide encouragement and support for villagers to concentrate agriculture on the development of high-yielding lychee orchards on the more productive and less ecologically sensitive lower slopes.

Who owns the site?

When trying to carry out conservation activities, the last thing you want is a land dispute. When planting on public land, make sure that you get written permission to plant trees, including a map, from the relevant authorities. Most public authorities welcome help with tree planting from community groups and NGO's, but obtaining written permission can take a long time, so start discussions at least a year before the intended planting date. Ensure that all the relevant officials are fully involved in all stages of project planning and implementation. It is important that everyone involved understands that planting trees does not constitute a legal claim to the land.

If planting on private land, make sure that the landowner (and his/her heirs) are fully committed to maintaining the area as forest. Tree planting considerably increases the value of private property, so private landowners should fully cover the costs of tree planting.

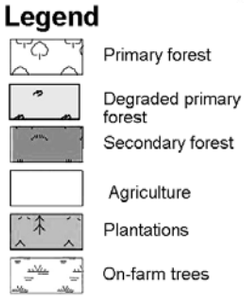
What should be the size and shape of planted plots?

The size of plots planted each year depends on the labour available for weeding and caring for the planted trees during the first two years after planting. This calculation is explained in Part 8.

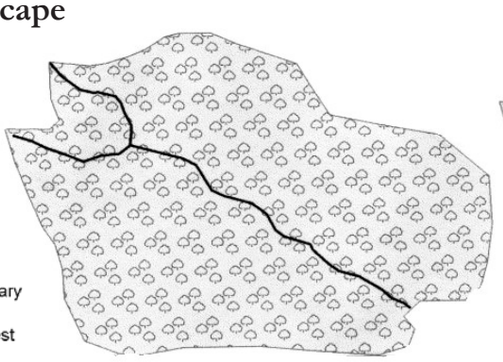
Bearing in mind "edge effects", already explained, the shape of the planting plot should have a minimal edge:area ratio. This makes a circle the ideal theoretical shape for plots, but it is not a practical shape to lay out on a large scale. As a rough rule, try to make the length and width of planted plots approximately equal and do not plant trees in long, narrow plots, unless your objective is to establish a riparian strip or a wildlife corridor joining two forest patches.

Biodiversity recovery will occur more rapidly if framework forest restoration plots are located adjacent to or nearby existing undisturbed forest.

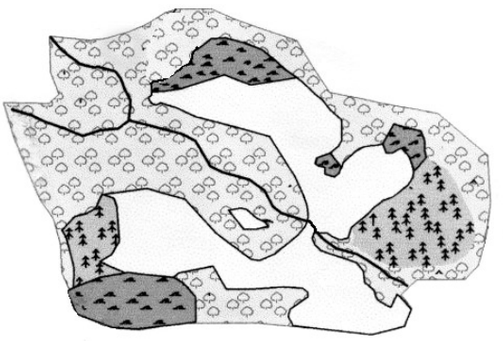
Forest Landscape Restoration



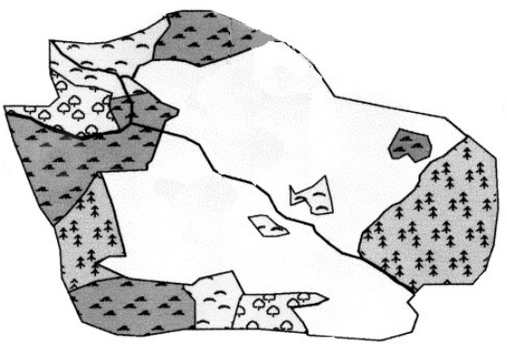
Source: Maginnis and Jackson (2002).



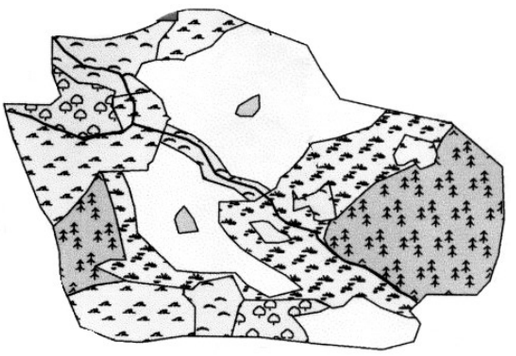
Original landscape, covered with primary forest.



Modified landscape - although land-use patterns have changed, the full range of forest products and ecological functions remain.



Degraded landscape - diminished tree cover has reduced supply of forest products and disrupted ecological functioning of the landscape.



Restored landscape - FLR aims to recover supply of forest products and provision of ecological services at the landscape level.

How do I survey a potential planting site?

All stakeholders (Part 8, Section 2) in a forest restoration project should participate in a survey of the proposed planting site, since it stimulates discussion of a wide range of issues that may affect project planning and implementation, including land rights, labour inputs *etc.* It also helps to build a consensus for the aims of the tree planting program and encourages long-term commitment.

A topographic map, showing forest cover, a compass and a camera are needed to carry out a site survey. It is also useful if a geographical positioning system device (GPS) can be borrowed, perhaps from a local education establishment.

Start with the topographic map (p113, A). Look at the contours to determine the elevation of the site. Look-up the elevation ranges of the framework tree species that are being considered for planting (Part 9) to make sure that they can grow at the elevation of the site. Next, use the contours and the map scale to determine the average site steepness. This will help to determine the risk of soil erosion (B) and how easy it will be to work on the site. Also consider access to the site (C). Look for roads or tracks. How far away from access points will trees and planting materials have to be carried on foot? Remember that planting and tree care take place mostly in the rainy season so, in the field, inspect the condition of access routes to determine if 4WD vehicles, elephants or some other form of transport for the trees and the planters may be needed.

On site, look for sources of natural forest regeneration (D). Estimate the density of naturally established trees, saplings or sprouting stumps. The recommended planting density of framework tree species is around 500 trees per rai (3,000 per ha), but this is for sites with no existing trees. The number of trees planted can be reduced to compensate for the density of naturally established trees or sprouting tree stumps, provided such sources of regeneration are protected from harm during site preparation.

Collect foliage specimens from the trees and sprouting stumps and get them identified by a botanist. Local, vernacular plant names are often ambiguous or used inconsistently, so always try to work with scientific names provided by a trained botanist. Common species of naturally established trees can obviously be omitted from the list of framework trees to be planted (see Table 3.1).

Next, turn your attention to weed cover (p 113 E & Part 3, Section 6). If weed cover is sparse, the labour required for plot preparation can be reduced. Short weeds may be dealt with by a single application of the non-residual herbicide, glyphosate (Round-up). Taller weeds must be slashed first. Then herbicide is applied a few weeks later, after they re-sprout (Section 2).

Then, look at the soil. If the soil is compacted, more labour will be needed to dig the planting holes and mulching will be essential to help improve soil structure. If possible, send some soil samples (F) to your local agricultural college or agricultural extension facility for analysis. This will help you determine how much fertilizer may be required to enable the planted trees to overcome any soil nutrient deficiencies that may be present.

Look for evidence of fire (blackened tree stumps *etc.*). This will help to determine what fire-prevention measures may be needed (Section 4). Also, look for signs of cattle. If necessary, discuss how cattle might be excluded from the site (Part 3 Section 6 and Part 4 Section 2).

Take plenty of photos. These will become an invaluable historical record, when assessing the success of the project years later. If you have a GPS (p113, G), use it to record the positions of the corners of the proposed planted plots and mark them with concrete or metal poles. Use string to create a temporary plot boundary.

Conclude the site survey by erecting a sign board (I), illustrated with a map of the location and extent of the plots to be planted. Display contact details of the project organizers, so that any local people, who may not have heard about the project, can offer help or raise objections.

Finally, use the topographic map to locate the nearest patch of natural forest (H) at a similar elevation to the proposed planting site. A visit to the forest will give all stakeholders a clear picture of the goal of forest restoration. Identify the forest type (see Part 2) and the tree species present and then take a fresh look at the list of tree species that you are planning to plant.

Section 2 - Preparing to Plant

When should trees be planted?

In seasonally dry tropical forest areas, the best time to plant trees is early in the rainy season, once rainfall has become regular and reliable. This gives the trees the maximum length of time to grow a root system that penetrates deep enough into the soil to obtain sufficient water during the first dry season after planting to prevent desiccation. In northern Thailand, the optimal planting time is mid-June to mid-July.

When should plots be prepared for tree planting?

Before planting, clear the plots of weeds. If this is done with a slow-acting, systemic herbicide, such as glyphosate (Round-up), start the process at least 6 weeks before the planned planting date (*i.e.* beginning of May in northern Thailand). If weeding is done entirely with hand tools, clear plots of weeds about 1-2 weeks before planting.

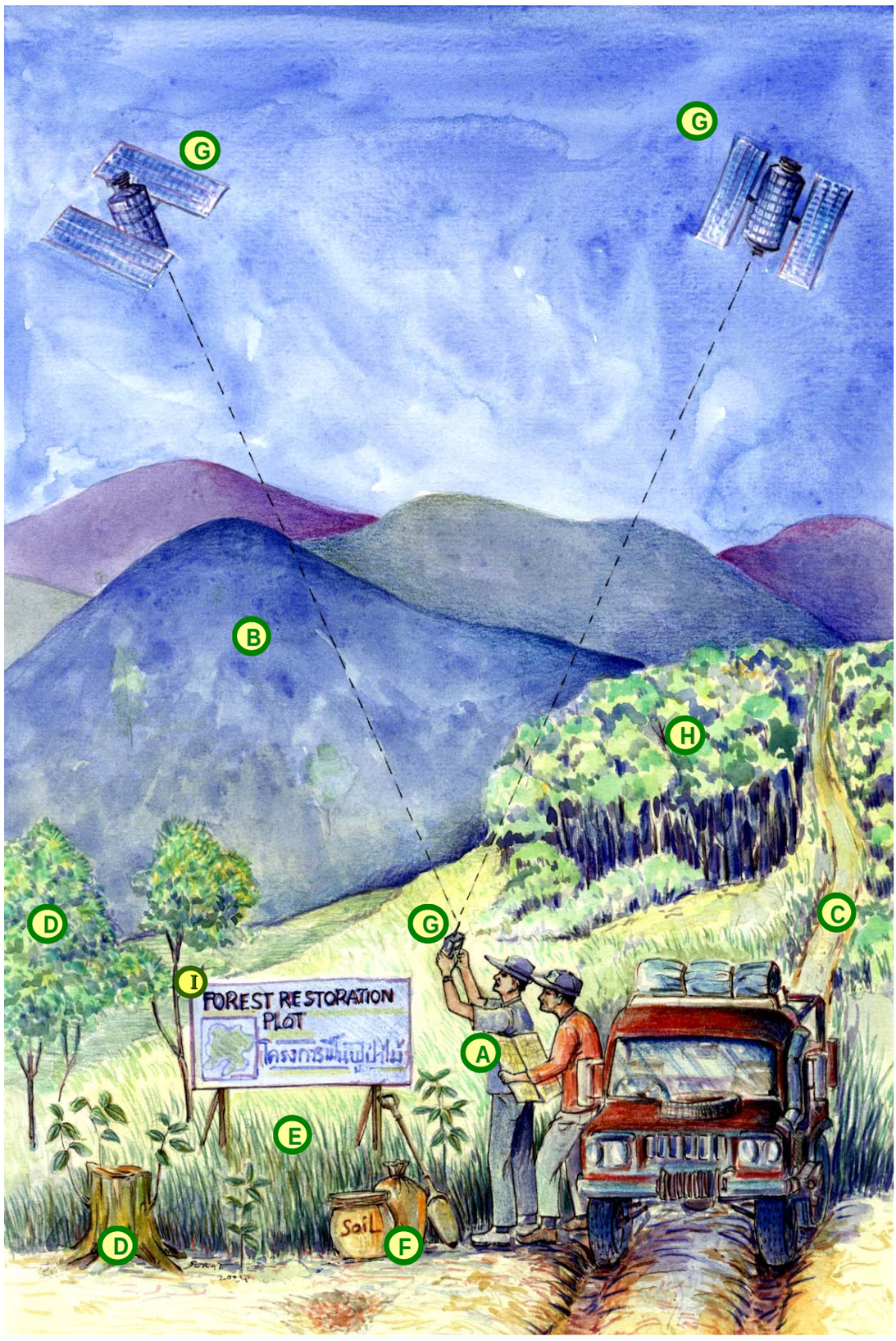
What about existing sources of forest regeneration?

First, take steps to protect any existing, naturally-established trees, seedlings, saplings or live tree stumps that may be present. Inspect the plots thoroughly, taking care not to miss smaller tree seedlings that may be obscured by weeds. Place a bamboo pole, painted with a bright colour, next to each plant found and dig out weeds, using a hoe, in a 1.5 m-diameter circle around each. This makes natural sources of forest regeneration more visible to workers, so they avoid damaging them when weeding or planting. It also releases natural seedlings from competition with weeds so that they can grow up beside the planted trees. Impress upon everyone working in the plots the importance of preserving these natural sources of forest regeneration.

Slashing Weeds

With bamboo poles, clearly mark all sources of natural forest regeneration, including seedlings, saplings and live tree stumps. Then, slash the weeds down to ground level, to prepare for herbicide application.

Making a Site Assessment



When surveying a potential planting site, consider steepness and susceptibility to soil erosion (B), accessibility (C), sources of natural forest regeneration (D), weeds (E) and soil conditions (F).Include a survey of the nearest patch of remaining forest (H) in your site assessment and use a topographic map (A) and GPS (G) to record the position of the plot. Finally, erect a signboard (I) to explain the project to all local people.

Planting Trees

It is easy to find enthusiastic volunteers to help to plant trees (above). Lay out plots with a compass, light metal poles and string (left).

Protect trees with shade netting during transportation (above). Getting trees and materials to remote sites can be a problem (right).

This is what happens if you do not weed (above). All trees are dead 1 year after planting; choked beneath a dense bracken fern canopy.

The perfectly planted tree, Mae Ow, Lampoon (above).

Slice open plastic bags with a box cutter (above). Try to keep the root ball and medium intact.

Weed around the planted trees and apply fertilizer as needed during the 1st and 2nd rainy seasons after planting (above).

After planting, give the trees a drink (above) - 2-3 litres per tree. Hire a tanker if necessary.

Can herbicide be used to clear plots for planting?

Yes, but first weeds must be slashed down to below knee height. Leave the slashed material in the plots. It will be used as mulch during tree planting and it will minimize soil erosion and protect soil micro-organisms in the mean time. Wait at least 2-3 weeks for the weeds to start to sprout afresh. Then spray the new shoots with glyphosate (Round-up).

How does glyphosate work?

Glyphosate kills all species of green plants. It rapidly breaks down in the soil, so it does not accumulate in the environment like other pesticides such as DDT. The chemical is absorbed through leaves and is translocated to all other parts of the plant, including the roots. Plants die slowly, gradually turning brown over 1-2 weeks.

Since entire plants are killed, weeds must grow back from germinating seeds. This takes much more time than re-sprouting from slashed shoots or root stocks. So, planted trees have about 6-8 weeks, immediately after planting, relatively free from weed competition. During this time, their roots can colonize soil formerly fully occupied by weed roots.

How should it be applied?

Apply the herbicide on a dry windless day, to prevent drift on to any naturally regenerating tree seedlings. Do not spray if rain is forecast within 24 hours after application. Rain and even dew, within a few hours after spraying, render the chemical ineffective.

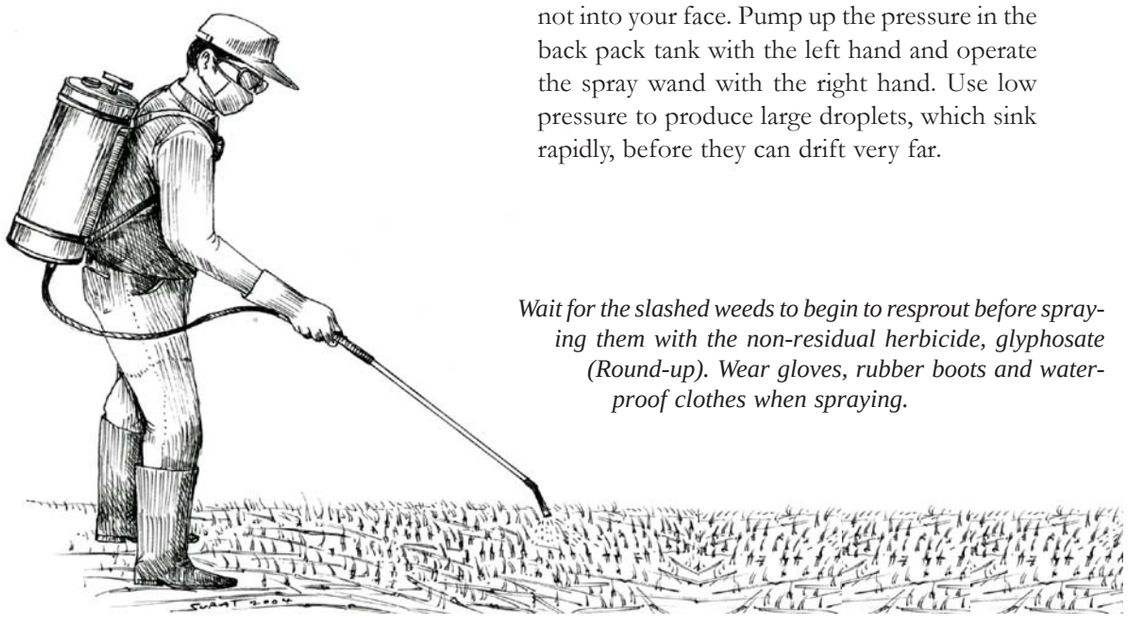
Large pumps mounted on pick-up trucks and long hoses, used to spray crops, are often available in agricultural communities. However, we recommend the use of 15-litre backpack tanks with directional spray nozzles, mounted on long wands to apply the glyphosate to clear land for forest restoration. This makes it easier to avoid accidentally spraying naturally established tree seedlings and saplings and prevents over-use of the chemical.

Put on rubber gloves and rubber Wellington boots. Wear a waterproof jacket and trousers. For added safety, a body suit (Dupont Tyvek 100% spun-bonded polyethylene) and mask may be worn, but these are not strictly necessary.

Pour 150 millilitres of the concentrate into a 15-litre-tank backpack sprayer and top up with clean water to the 15-litre mark. You will need 6-8 tank-fulls (900 ml to 1.2 litres of the concentrate) per rai (or 37-50 tank-fulls, 5.6-7.5 litres of concentrate per hectare).

If you accidentally spray the chemical on your skin or in your eyes, wash with large amounts of water and get medical attention. Check the wind direction. Work with the wind behind you, so that the spray is blown forwards; not into your face. Pump up the pressure in the back pack tank with the left hand and operate the spray wand with the right hand. Use low pressure to produce large droplets, which sink rapidly, before they can drift very far.

Spraying Herbicide



Wait for the slashed weeds to begin to resprout before spraying them with the non-residual herbicide, glyphosate (Round-up). Wear gloves, rubber boots and waterproof clothes when spraying.

Walk slowly across the site, spraying strips about 3 m wide, by making gentle sweeps from side to side in front of you. Remember where you have been, to avoid spraying the same area twice. Adding a dye to the glyphosate makes it easier to see where you have already sprayed.

Glyphosate kills all plants, including tree seedlings and saplings, so keep a keen look out for them and keep the wand close to the ground. If you accidentally spray a tree seedling or sapling, immediately tear off any leaves where drops of the herbicide have fallen so that the chemical is not absorbed into the plant and transported to the roots.

As soon as possible after spraying, take a shower and wash all clothes worn during spraying. Clean all equipment used (backpacks, boots and gloves) with large quantities of clean water. Make sure that the waste water does not flow into a drinking water supply. Let it seep slowly into a sump pit or into the ground where there is no vegetation, far away from any water course.

Is glyphosate dangerous?

If basic safety instructions are ignored, glyphosate can damage people's health and the environment. So before using it, **read and follow the instructions provided by the supplier**. It has low toxicity to mammals (including humans) but it is toxic to fish, so don't clean any contaminated equipment in streams or lakes. Research is also beginning to show that it may affect soil micro-organisms. However, these minor potential damaging effects of the chemical on the environment must be weighed against the far more damaging long-term consequences of failing to restore forest ecosystems to the environment. Glyphosate is used only once, at the beginning of the forest restoration process. Use of the chemical after trees have been planted, is not recommended.

Isn't it safer to clear plots with hand tools?

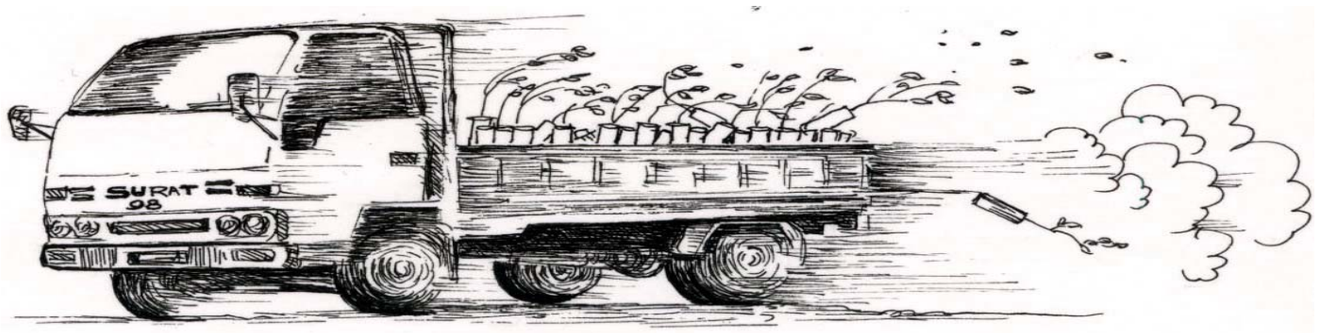
Large numbers of people, wielding machetes and hoes, can cause injuries and damage the environment too, but if you do not want to use a herbicide, there is no alternative. First slash weeds with machetes down to a reasonable height; then dig them out by their roots with a hoe. Make sure a first aid kit is on hand to deal with accidents.

Why dig out the roots?

Merely slashing weeds will only encourage them to re-sprout. As they do so, they absorb more water and nutrients from the soil than if they had never been cut in the first place. This actually intensifies root-competition with the planted trees, rather than reduces it. So, digging out the roots is essential, although the labour

SLOW DOWN !!!

Don't throw away a year's work in the nursery on the journey to the planting site. When transporting saplings, drive with care. Protect them beneath shade netting and don't stack them on top of each other.



required to do so is considerable. Unfortunately, digging out roots also disturbs the soil, increasing the risk of soil erosion. Furthermore, there is a significant risk of accidentally slashing naturally established tree seedlings/saplings.

For these reasons, and to reduce labour costs, we recommend use of glyphosate to clear plots for planting (but NOT for weeding after planting, see Section 4).

Can fire be used to clear plots?

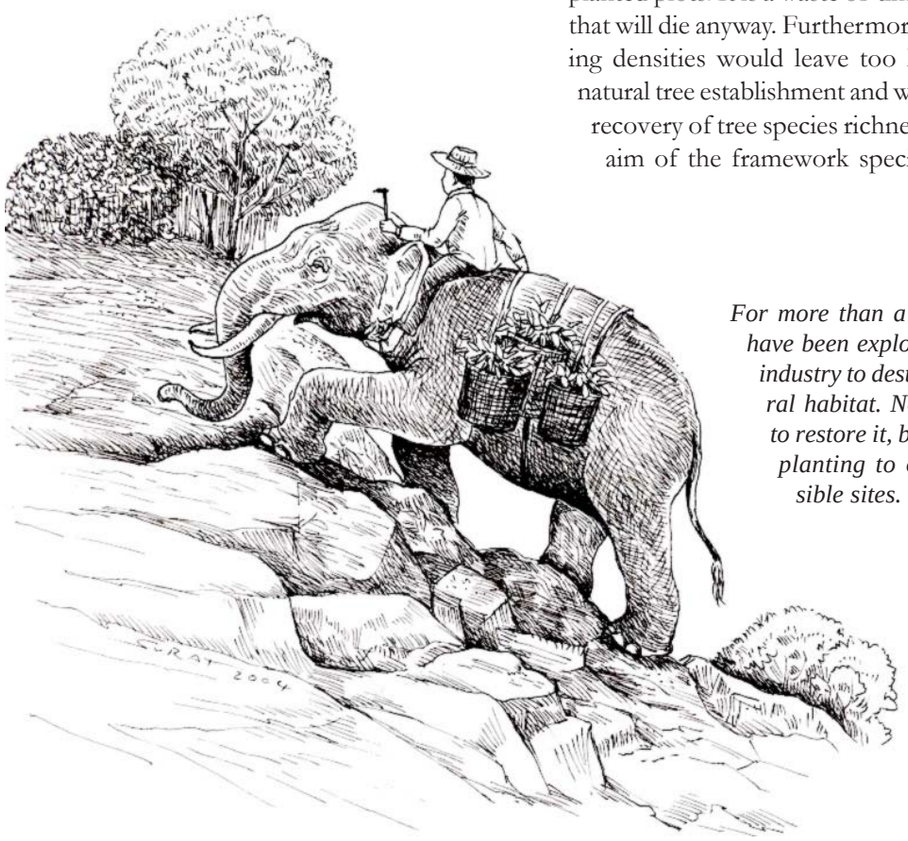
Definitely not. Fire kills any naturally established young trees that may be present, whilst stimulating re-growth of some perennial grasses and other weeds. It also kills beneficial micro-organisms, such as mycorrhizal fungi, and removes the possibility of using slashed weeds as mulch. Organic matter is burnt off and soil nutrients are lost in smoke. There is also a risk that fires, intended to clear a planting plot, may spread out of control to damage nearby forest or crops.

How many saplings should be delivered to the plots?

The final combined density of planted plus naturally established trees should be about 500 trees per rai (or 3,125 per ha), so the required number of saplings delivered to each 1-rai plot should be 500 minus the estimated number of naturally established trees or live tree stumps. This results in an average spacing of about 1.8 m between planted saplings or the same distance between planted saplings and naturally established trees (or live stumps).

This is much closer than the spacing used in most commercial forestry plantations, because the objective is to close canopy, shade out weeds and eliminate the costs of weeding, as quickly as possible. Remember, shade is the most cost effective and environmentally friendly herbicide. Planting fewer trees would mean that weeding would have to be continued for many years and consequently total labour costs to achieve canopy closure would be higher.

If the density of trees were higher than 500 per rai, the slower growing species would not be able to compete with faster growing ones, resulting in competitive thinning of the planted plots. It is a waste of time to plant trees that will die anyway. Furthermore, higher planting densities would leave too little room for natural tree establishment and would thus delay recovery of tree species richness, which is the aim of the framework species method.



For more than a century, elephants have been exploited by the logging industry to destroy their own natural habitat. Now they could help to restore it, by carrying trees for planting to otherwise inaccessible sites.

How many framework tree species should be planted?

Aim to deliver 20-30 species to each plot. Planting more species will accelerate biodiversity recovery, since different wildlife species are attracted to different tree species. However, trying to produce enough saplings of more than 30 species complicates seed collection and nursery management and is not strictly necessary.

How should saplings be transported to the planting plots?

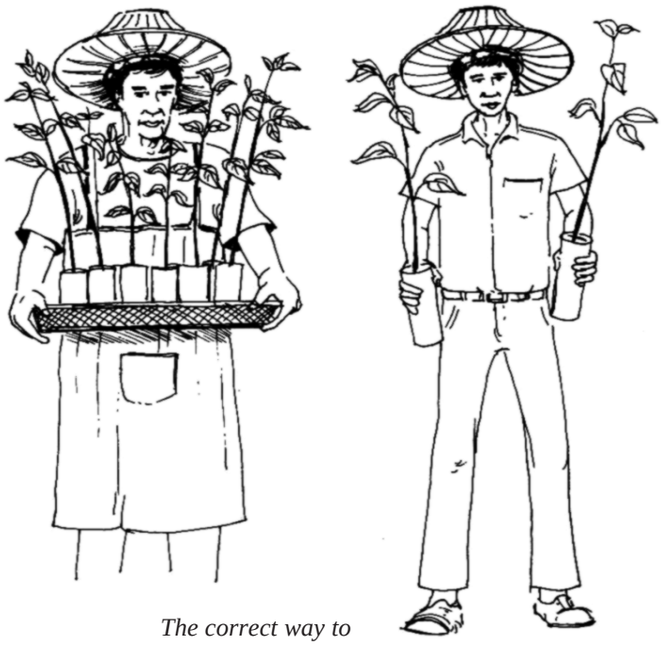
Select only the most vigorous saplings from the nursery, after grading and hardening-off (see Part 6 Sections 6 and 7 respectively). Label the saplings that you intend to include in your monitoring program (see Section 5). Then place all saplings upright in sturdy baskets and transport them to the planting plot, the day before planting.

Even saplings of the highest quality can be damaged by overheating and dehydration during transport to the planting plot. Furthermore, excessive movement can damage fine roots close to the sides of containers. The shoot system may also be damaged, if the containers are not packed carefully in the vehicle.

Some basic precautions can prevent these problems. Water the saplings just before loading them into the vehicle. Make sure containers are packed upright to prevent spillage of potting mix. If plastic bags are used, do not pack them so tightly that they lose their shape. Also, do not stack containers on top of each other, since this will crush shoots and break stems.

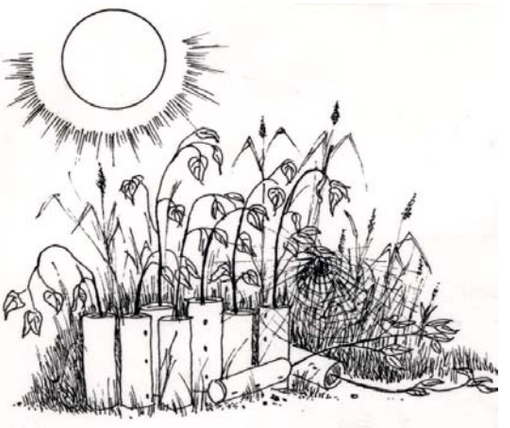
If an open truck is used, cover saplings with a layer of shade netting to protect them from wind damage and dehydration. Drive slowly.

In the plots, place saplings upright beneath any available shade and, if possible, lightly water them again. If you have enough baskets, keep the saplings in baskets, since this makes it easier to carry them around the plot on planting day.



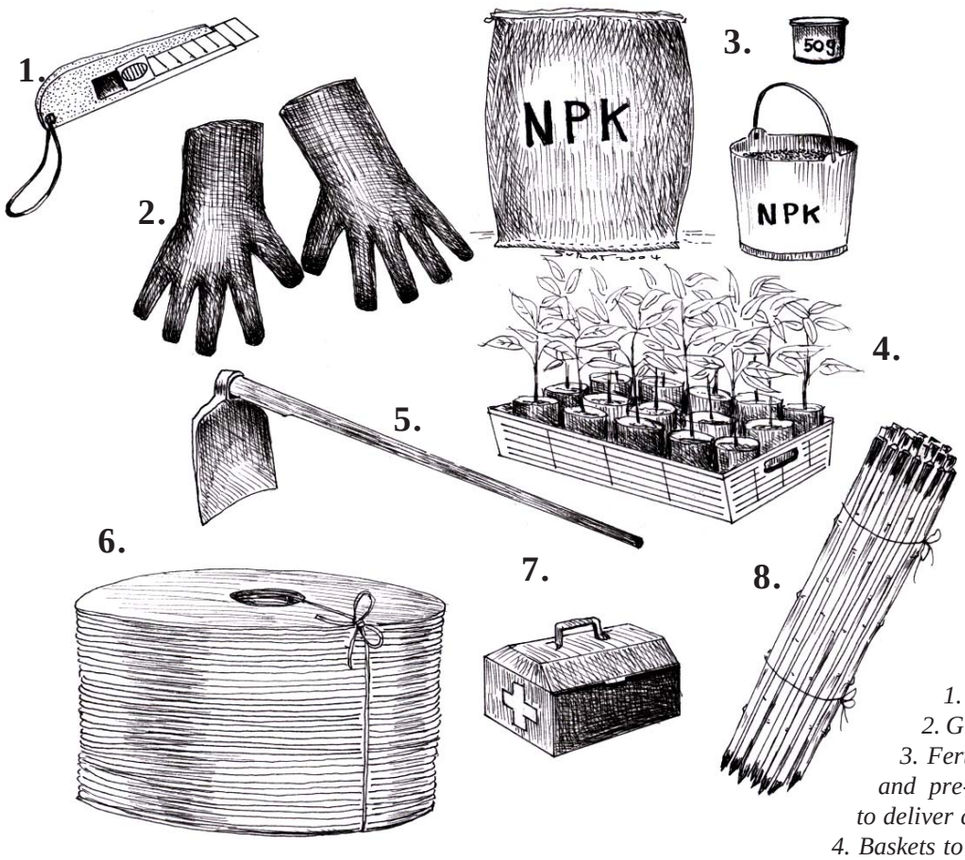
The correct way to carry saplings.

***DO NOT** carry saplings like this. It damages the stems.*



***DO NOT** leave saplings on site like this - exposed to the sun. Find some natural shade or make a temporary shelter with shade netting.*

Essential Tree Planting Equipment



1. Knife
2. Gloves
3. Fertilizer, bucket and pre-measured cups to deliver correct dose
4. Baskets to distribute saplings
5. Hoes for hole-digging
6. Cardboard mulch mats
7. First aid kit
8. Bamboo poles.

What materials should be delivered to the planting site?

Along with the saplings, the day before planting, transport planting materials to the plots. These include a bamboo stake and a cardboard mulch mat for each sapling to be planted and a 50-kg-sack of fertilizer (25 kg) per rai to be planted (or 3 sacks (162 kg) per hectare). Protect these materials from rain by covering them in a tarpaulin.

What else needs to be done before the big day?

A few days before the planting event, hold a meeting of all project organizers. Appoint a team leader for each group of planters. Make sure that all team leaders are familiar with the tree planting techniques described in Section 3 and that they know precisely which area each will be responsible for planting. You will need about 8-10 planters per rai to finish the job in one day (50-62 per hectare).

Ask the team leaders to tell their team members to bring gloves, box-cutters (to slash open plastic bags), buckets and cups for fertilizer application and hoes or small shovels (to fill in the planting holes). In addition, team leaders should advise the planters to wear a hat, to protect them from the sun and carry a bottle of water with them. Planters should also be instructed to wear sturdy footware, a long-sleeved shirt and long trousers (to protect themselves from cuts and scratches).

Make a final estimate of the number of people likely to participate in the planting event. Organize enough vehicles to take everyone to the plots and arrange enough food and drink to keep everyone well fed and hydrated. Make contingency plans in case of bad weather. Finally, consider whether the project and the local community might benefit from media coverage of the event and, if so, contact journalists and broadcasters.

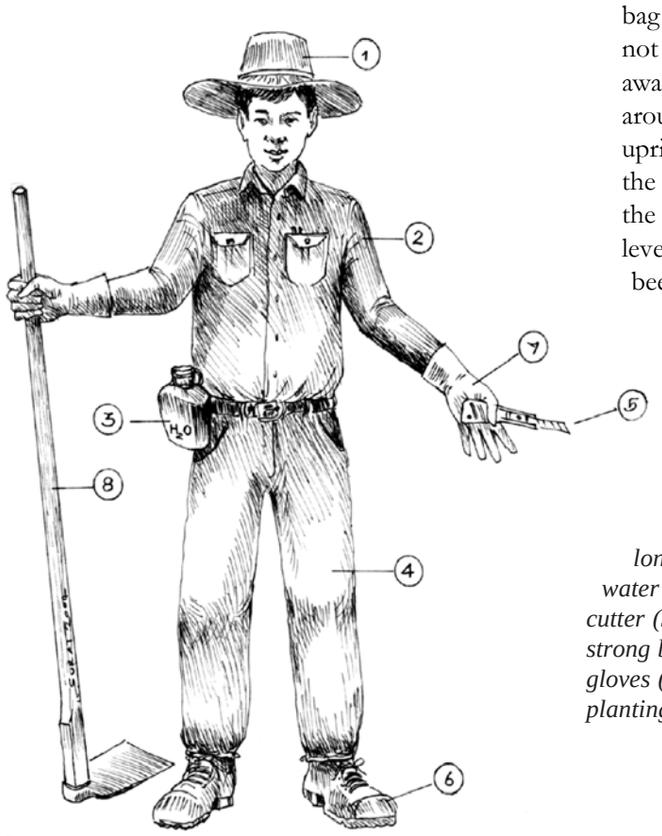
SECTION 3 – THE PLANTING EVENT

Tree planting events do much more than just put trees in the ground. They provide an opportunity for ordinary people to become directly involved in improving their environment. They are also social events, helping to build community spirit. Furthermore, with the help of media coverage, they can portray a positive image of communities as responsible stewards of the natural environment.

Tree planting can also have an educational function. Participants can learn, not only ***how*** to plant trees, but also ***why***. Take time at the beginning of the event to demonstrate the planting techniques to be used and make sure everyone understands the objectives of the forest restoration project. Also, take the opportunity to invite everyone to participate in future follow-up operations, such as weeding, fertilizer application and fire prevention.

How far apart should saplings be planted?

The first step of tree planting is to mark where each tree will be planted with a 50-cm tall bamboo stake. Space the stakes about 1.8 metres apart or the same distance away from naturally established trees or tree stumps. Try not to position the stakes in straight rows. A random arrangement will give a more natural structure to the restored forest. Staking out the plots can either be done on planting day or a few days in advance.



The perfectly prepared planter, with hat (1) to protect him from the sun; long-sleeved shirt (2); plenty of water (3); long trousers (4); a box cutter (5) to slash open plastic bags; strong boots (6) to protect his feet; gloves (7) and a hoe (8) to dig the planting holes.

How should the saplings be planted?

Use baskets to distribute one sapling to each of the stakes. Mix up the species so that saplings of the same species are not planted next to each other.

Beside each bamboo stake, use a hoe to dig a hole, approximately twice the volume of the sapling's container. At the same time, use the hoe to drag away dead weeds in a circle 50-100 cm in diameter around the hole.

If saplings are in plastic bags, slash each bag up one side with a sharp blade, taking care not to damage the root ball inside. Gently peel away the plastic bag. Try to keep the medium around the root ball intact. Place the sapling upright in the hole and pack the space around the root ball with loose soil, making sure that the sapling's root collar is eventually positioned level with the soil surface. If the sapling has been labeled for monitoring, make sure that the label does not become buried.

1. Stake out the site.

2. Dig holes twice the size of the containers

With the palms of your hands, press the soil around the sapling stem to make it firm. This helps to join pores in the nursery medium with those in the plot soil, thus rapidly re-establishing a supply of water and oxygen to sapling's roots.

Next, apply 50-100 g fertilizer in a ring on the soil surface, about 10-20 cm away from the sapling stem. If fertilizer contacts the stem, chemical burning can occur. Use pre-measured plastic cups to apply the correct dosage of fertilizer.

Then (optionally) place a cardboard mulch mat, 40-50 cm in diameter around each planted sapling. Anchor the mulch mat in position by piercing it with the bamboo stake. Pile up dead weeds onto the cardboard mulch mat.

At the end of the planting event, if there is a water supply nearby, water each planted sapling with at least 2-3 litres. A water tanker can be hired to deliver water to sites that are accessible by road but distant from natural water supplies. For inaccessible sites with no available water, schedule planting to take place when rain is forecast.

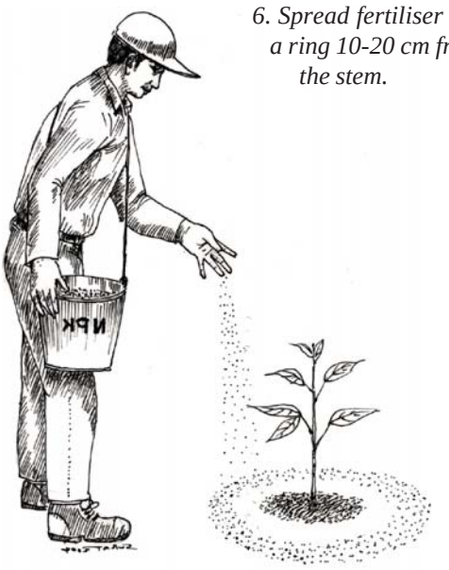
The final task is to remove all plastic bags, spare poles or cardboard mulch mats, and garbage from the site. Team leaders should personally thank all those taking part in the planting. A social event to mark the occasion is also a good way to thank participants and build support for future events.

3. Remove saplings from containers keeping root ball intact.

4. Place sapling in hole and fill in with loose soil.

5. Firm down soil around the planted sapling.

6. Spread fertiliser in a ring 10-20 cm from the stem.



What kind of fertilizer should be used?

For upland sites, ordinary chemical fertilizer N:P:K 15:15:15 produces good results. Spreading the fertilizer in a ring around the base of the tree is more effective than placing fertilizer in the planting hole, since the nutrients percolate down through the soil as the roots begin to grow into the surrounding soil. On lowland sites, with very poor soils, we have recorded slightly better results using a pelleted organic fertilizer, made from animal waste (Phogaruna Brand). This may be because this type of fertilizer breaks down and is leached from the soil more slowly than chemical fertilizer is. Thus, it delivers nutrients to the tree roots more evenly over a longer period.

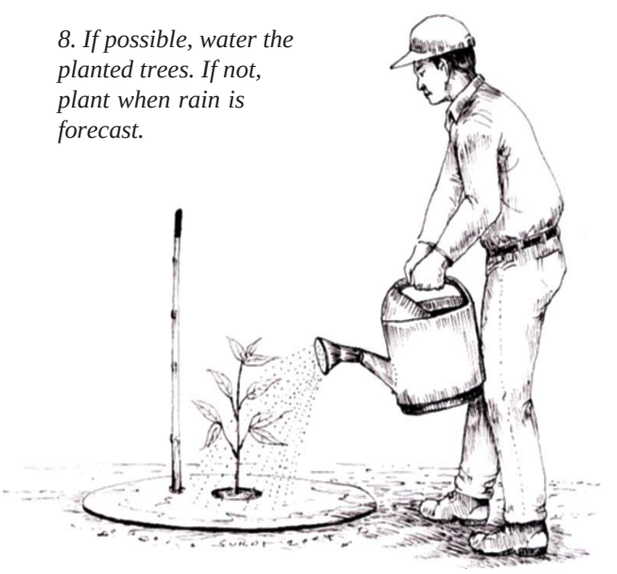
What is the function of a mulch mat?

Mulch mats made of corrugated cardboard can increase the survival and growth of planted saplings, particularly where soils are at risk of drying out immediately after planting. Such mats are particularly recommended when planting deciduous forest trees in the lowlands on lateritic soils.

Most weed seeds are stimulated to germinate by light. Placing mulch mats around planted saplings blocks out light and thus prevents weeds from re-colonizing the ground in the immediate vicinity of planted trees. Furthermore, mulch mats help to keep the soil cool, which reduces evaporation of soil moisture.

7. Lay cardboard mulch and stake it in place with the bamboo pole.

8. If possible, water the planted trees. If not, plant when rain is forecast.



Fire

Annually, since 1998, the villagers of Ban Mae Sa Mai have organized an effective fire prevention program. One member of each family joins a work team to cut fire breaks around planted sites in mid-January (right).

During the dry season, each household contributes one member every 11 days to join a 16-person fire team, which spots fires and prevents them spreading to the planted plots (left). So, the workload of fire prevention is shared equally across the community (see Part 8).

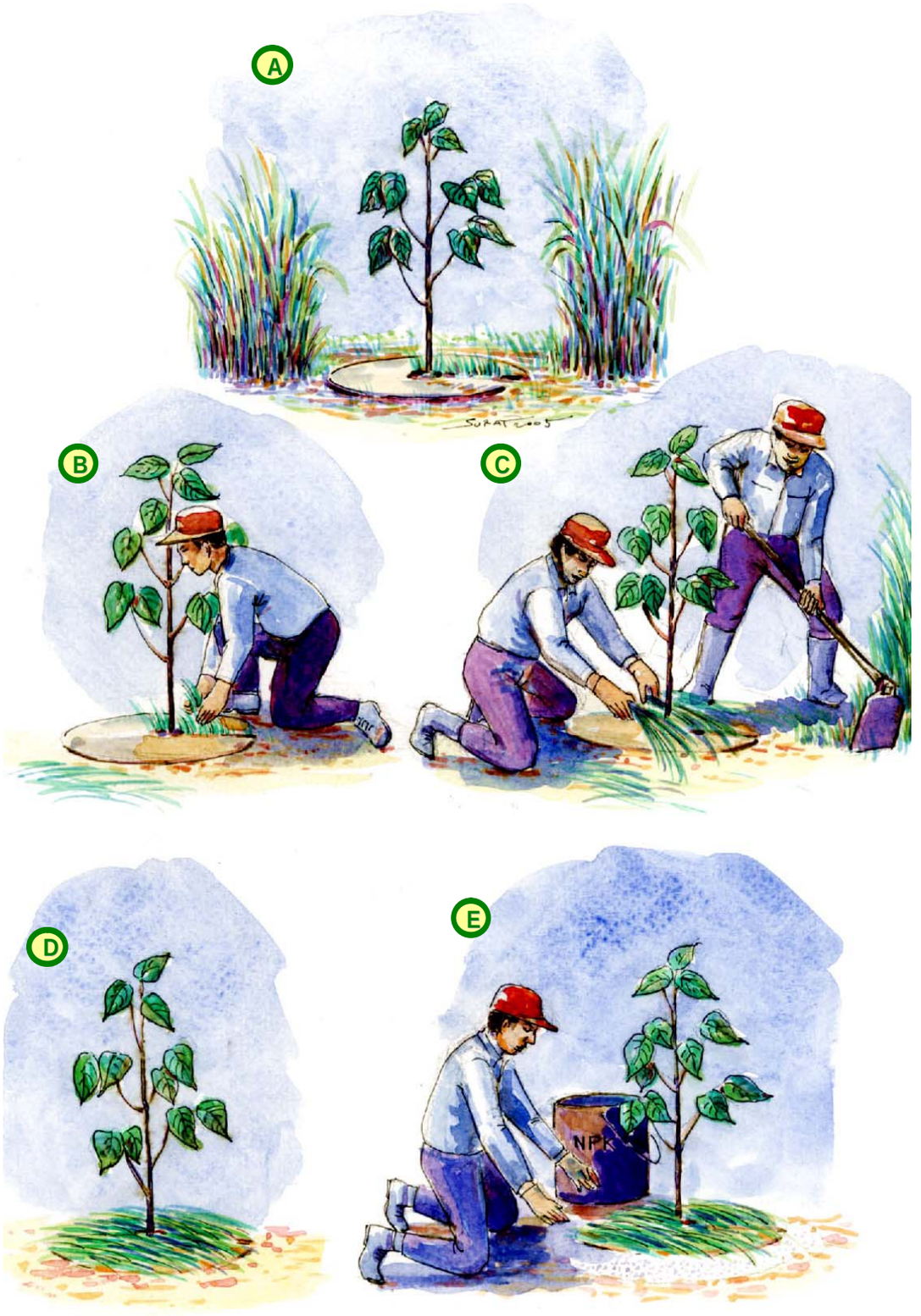
FORRU-CMU and the Forest Department co-sponsor food for the fire team and religeous ceremonies (above).

At the beginning of the fire season, the village spirits are asked to help save the planted trees from burning (left). If the fire prevention program is successful, another ceremony to thank the spirits is performed. A pig is slaughtered for a feast to reward both the spirits and the fire prevention team (above).

Some tree species are more resilient to fire than others. This Prunus cerasoides *tree (right) was burnt 8 months after planting. The original stem is dead but, 3 months after burning, a new stem has sprouted from the root collar.*

Small fire trucks (left) are only practical near roads.

Weeding is Essential



Weeding is essential to keep planted trees alive during the first two rainy seasons after planting. A cardboard mulch mat can help keep weeds down to a minimum immediately around the tree stem (A). Pull out any weeds growing near the tree base by hand (wear gloves) to avoid damaging the tree roots (B). Try to keep the mulch mat intact. Next, use a hoe to root out weeds in a circle around the mulch mat (C) and lay the uprooted weeds on top of the mulch mat (D). Finally, apply fertilizer (50-100 gm) in a circle around the mulch mat (E).

Soil invertebrates are attracted by the cool, moist conditions beneath the mats. They churn up the soil around planted saplings, improving drainage and aeration.

Cardboard mulch mats should be circular, about 40-50 cm in diameter, with a hole in the middle about 5-10 cm across and a narrow slit, from the circle perimeter to its centre. Open the circle along the slit and place the hole in the middle centrally around the tree stem. Make sure that the cardboard does not touch the stems of the planted tree, since it may abrade them, creating wounds, which can become infected by fungi. Drive a bamboo stake through the mat to keep it in place.

Cardboard mats last one rainy season, gradually rotting down and adding organic matter to the soil. Replacing mats at the beginning of the second rainy season does not seem to result in additional beneficial effects (FORRU-CMU data).

What about polymer gel?

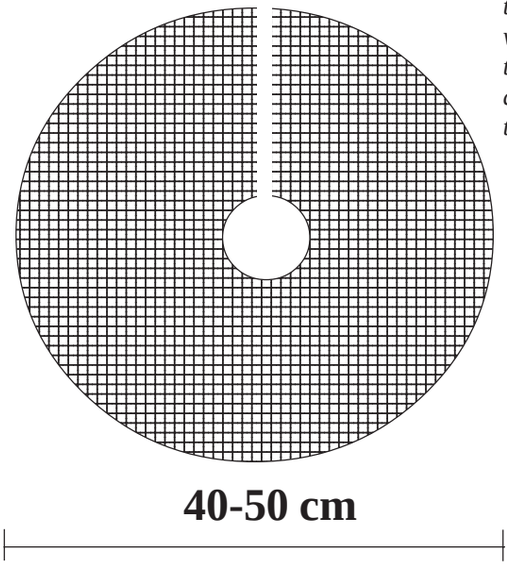
Water-absorbent polymer gel can help keep the roots of planted trees hydrated and reduce transplantation stress. On well-watered highland sites, it is usually unnecessary, but we have found that polymer gel, used in combination with cardboard mulch mats, significantly reduces immediate post-planting mortality amongst deciduous forest trees, when they are planted in dry areas on poor soils.

Polymer gel is widely available from most agricultural supplies shops. Similar products, derived from local materials such as rice and corn starch, are under development. Mix the gel with water, according to the instructions on the packet. Then mix 1-2 litres of hydrated gel with loose soil in each planting hole, just before planting the trees.

What happens after the planting is over?

Most planting events involve large numbers of volunteers. Even with a demonstration of planting techniques at the beginning of the event, it is inevitable that some trees may not be planted properly. So, once the planters have left the site, team leaders should inspect the planted trees and correct errors. Make sure that all the trees are upright, that the soil around them has been properly firmed down and that monitoring labels have not become buried. Look for any saplings that have not been planted and either plant them or return them to the nursery. Refill any holes with no trees in them. Remove any garbage or spare materials that may have been left behind.

Mulch Mats



Mulch mats, cut from recycled corrugated cardboard, are cheap and effective at reducing immediate post-planting mortality of planted trees; particularly on drought-prone sites with poor soils. They suppress weed growth and thus reduce the labour costs of weeding. Fertilizer is applied in a ring around the edge of the mat. Mats last about a year, if care is taken not to disturb them during weeding operations.

Section 4 – Caring for Planted Trees

In deforested sites, planted trees must endure hot, dry, sunny conditions as well as competition from fast-growing weeds. In addition, during the dry season, there is a risk that fire will destroy them. Intensive care of the trees during the first 18 months after planting can significantly reduce these risks. Consequently, although caring for planted trees involves costs and hard work, it is more cost effective than having to replant trees which die. Provided the procedures outlined below are followed and the planted saplings are healthy, vigorous and well hardened-off, the planted forest should become self-sustaining, requiring little or no further maintenance, within 3 years and consequently no subsequent planting should be necessary.

How often is weeding necessary?

The frequency of weeding depends on how fast the weeds grow. On upland sites, weed growth is very rapid during the rainy season. After planting, it is recommended to weed around the planted trees at least 3 times during the rainy season at 4 to 6-week intervals. In the lowlands, weeds usually grow more slowly and more sparsely, so it may be possible to reduce the weeding frequency. Visit the site frequently to observe weed growth. Carry out weeding well before the weeds grow above the height of the planted trees. Do not carry out weeding after the end of November[1]. This allows some weed growth to occur before the onset of the hot, dry season. This can help to shade the planted trees and prevents desiccation during the hottest period of the year. However, it also increases fire risk, so only do this where fire prevention measures are effective. Where fire is particularly likely, try to keep planted plots free of weeds at all times. The labour force required for weeding varies with the weed density but, to complete the job in a single day, 3-4 weeders per rai (20-25/ha) will be needed.

How long must weeding be continued?

Frequent weeding is essential during the first two rainy seasons after planting. It is not usually necessary to weed during the dry season. In the third rainy season after planting, the frequency of weeding can be reduced as the crowns of the planted trees begin to meet and form a forest canopy. By the fourth rainy season, the shade of the forest canopy should be sufficient to prevent weed growth.

How should weeding be done?

Wear a pair of gloves and gently pull out any weeds growing close to tree stems, including any growing through cardboard mulch mats. Try not to disturb the mulch mats too much. Around the mats, use a hoe to dig out weeds by their roots. Lay uprooted weeds around the trees, on top of the mulch mats. This maintains shading of the soil surface, and inhibits germination of weed seeds even as the mulch mat rots away. Try to ensure that uprooted weeds do not touch the tree stems, as this can encourage fungal infection.

Use of machetes or weed whackers close to planted trees is strongly discouraged, to prevent accidentally slashing them, although such tools may be useful to control weeds between the trees. Apply fertilizer immediately after weeding around each tree.

How frequently should fertilizer be applied?

Even on fertile soils, most tree species benefit from application of additional fertilizer during the first two rainy seasons after planting. It enables the trees to grow above the weeds rapidly and shade them out, thus reducing weeding costs. Apply 50-100 g fertilizer, at 4 to 6-week intervals, immediately after weeding, in a ring about 20 cm away from the tree stem. If a cardboard mulch mat has been laid, apply the fertilizer around the edge of the mulch mat.

Chemical fertilizer (N:P:K 15:15:15 Rabbit Brand) is recommended for upland sites, whilst organic pellets (Phogaruna Brand) produces significantly better results on lateritic lowland soils. Application of fertilizer too close to the

[1]except for those tree species listed in Part 9 that benefit from later weeding

stems of planted trees can damage or kill them. Weeding before fertilizer application ensures that the planted trees benefit from the nutrients and not the weeds.

How can fires be prevented?

Fire is an annual hazard during the dry season and can wipe out years of hard work in an instant. Although fires can occur naturally, most are started by humans, so the best way to prevent them is to make sure that everyone in the vicinity supports the tree planting program and understands the need not to start fires anywhere near the planted sites. However, no matter how much effort is put into raising awareness of fire prevention amongst local communities, fire remains the most common cause of failure of forest restoration projects. Although fire suppression units of the Forest Department can help put out fires, they cannot be everywhere, so local, community-based fire control initiatives are often more effective. In addition to public education, fire prevention measures include cutting fire breaks and organizing fire patrols to detect approaching fires and extinguish them before they can spread to planted sites.

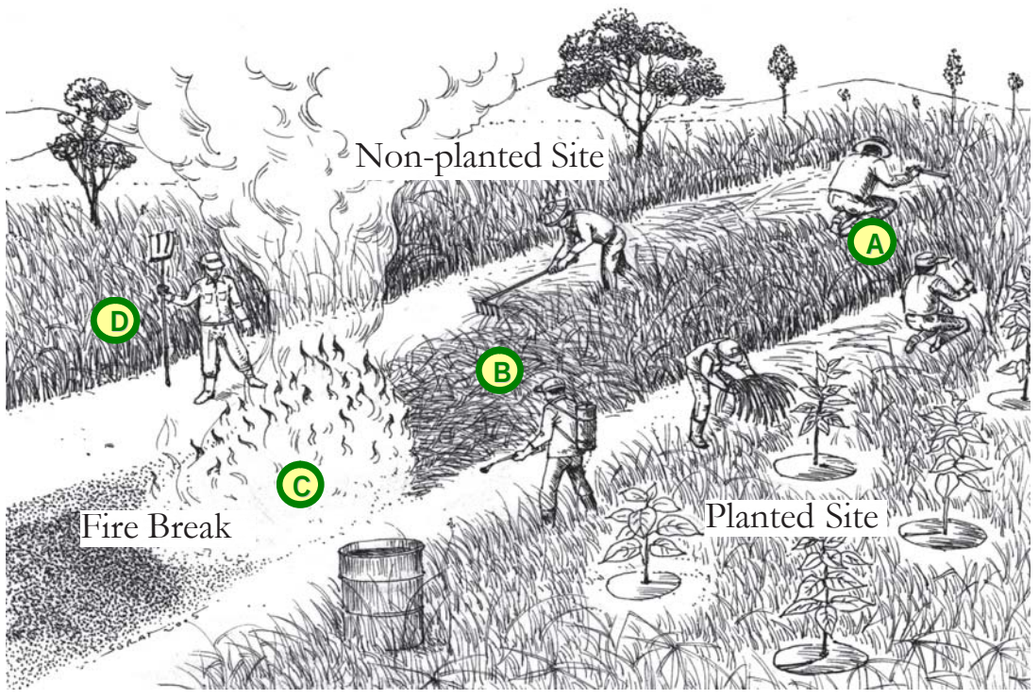
How are fire breaks made?

Fire breaks are strips of land that are cleared of combustible vegetation to prevent the spread of fire. They are effective at blocking moderate, ground-cover burns. More intense fires throw up burning debris, which can be blown across fire breaks to start new fires far away from where the original fire ignited.

Make firebreaks 10 to 15 m wide around planted sites, just before onset of the hot, dry season (mid-January in northern Thailand). The quickest method is to slash all grasses, herbs and shrubs (trees need not be cut) along the two edges of the firebreak. Pile up cut vegetation in the centre of the firebreak. Leave it for a few days to dry out and then burn it. Obviously, using fire to prevent fire can be risky. Make sure plenty of people are available, with beaters and water sprayers, to prevent accidental escape of the fire into surrounding areas. By burning fire breaks just before temperatures soar at the beginning of the hot, dry season, the risk of fire escaping is considerably reduced, since surrounding vegetation retains sufficient moisture not to burn easily. Roads and streams act as natural fire breaks, so there is usually no need to make firebreaks along them.

Making a Firebreak

Use fire to fight fire. (A) Slash two strips of vegetation 10 - 15 m apart. (B) Drag the cut vegetation into the centre. (C) Allow a few days for the cut material to dry out, then burn it off, taking extreme care not to allow the fire to spread outside the firebreak (D).



How can fires be suppressed?

Organize teams of fire watchers to alert local people when fires are spotted so that they can help to extinguish them. Try to involve the whole community in the fire prevention programme, so that each household contributes one family member every few weeks to fire prevention duties. Fire watchers must remain alert night and day from mid-January until mid-April, or until whenever the first rains occur.

Place fire fighting tools and oil drums full of water at strategic places around the planted site. Fire fighting tools include back-pack water tanks with sprayers, beaters to smother the fire, rakes to remove combustible vegetation from the fire front and a first aid kit. Green tree branches can be used as fire beaters. If a permanent stream runs nearby, above the planting site, consider laying pipes into the planted sites. This can greatly increase the efficiency of fire fighting activities, but is very expensive.

Only low intensity, slow moving, ground fires can be controlled with hand tools. More serious fires, especially those that move up into tree crowns, must be controlled by professional fire fighters with aerial support. Be ready to contact local fire fighting authorities if the fire gets out of control.

Most local forest fire control units of the Royal Forest Department are happy to provide training to local people in fire prevention and fire fighting techniques and to supply fire fighting equipment to community-based fire prevention initiatives, so please contact your local forest fire control unit for assistance.

What can be done if planted plots do burn?

All is not lost, especially if some of the framework tree species planted were selected for their fire resilient characteristics. Although no trees are fire-proof, many species can grow back rapidly after having been burnt. Usually this involves re-sprouting from dormant buds around the root collar; "coppicing".

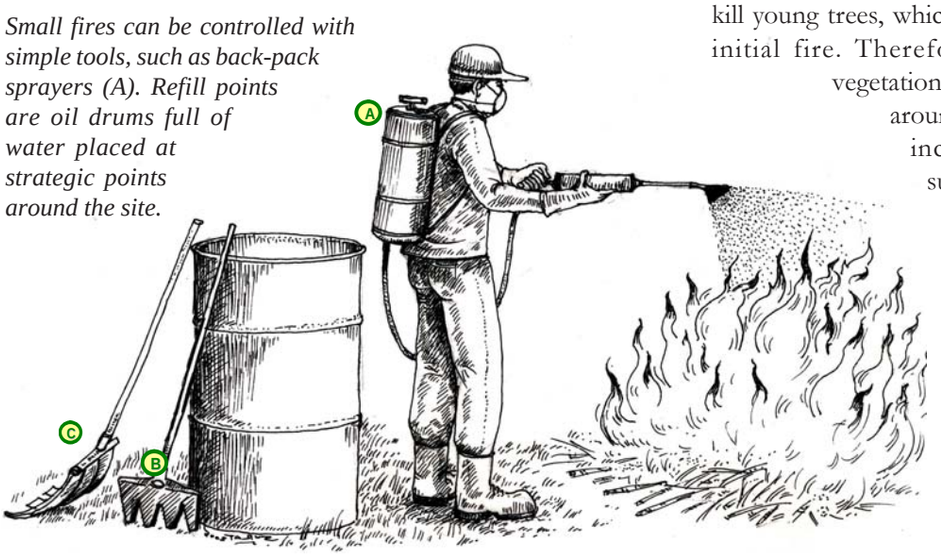
Larger (and older) trees are more likely to re-grow after having been burnt than smaller ones. Most trees with a root collar diameter (RCD) of 5 cm or larger can survive a moderate ground-cover burn. This size is usually reached by the end of the third rainy season after planting for most of the framework species described in Part 9. Younger trees are more vulnerable, but some with RCDs as small as 2 cm may occasionally survive fire.

Framework tree species that are particularly resilient after fire, even within one year after planting, include *Acrocarpus fraxinifolius, Archidendron clypearia, Castanopsis acuminatissima, C. tribuloides, Ficus altissima, F. hispida, F. racemosa, Glochidion kerrii, Gmelina arborea, Heynea trijuga, Hovenia dulcis, Lithocarpus fenestratus, Machilus kurzii, Melia toosendan, Magnolia baillonii, Phyllanthus emblica, Prunus cerasoides, Rhus rhetsoides* and *Sarcosperma arboreum.*

Burnt, dead branches allow entry of pests and pathogens, so cutting them off can speed recovery after burning. Prune dead branches right back, leaving a stump no longer than 5 mm. After fire, the blackened soil surface absorbs more heat, causing more rapid evaporation of soil moisture. This can subsequently kill young trees, which may have survived the initial fire. Therefore, laying mulch (cut vegetation or corrugated cardboard) around young, burnt trees can increase their chances of survival and re-growth.

Fire Control

Small fires can be controlled with simple tools, such as back-pack sprayers (A). Refill points are oil drums full of water placed at strategic points around the site.



Starve the fire of fuel by using a rake (B) to drag away flammable vegetation from approaching flames. Beat out flames with leather beaters (C) or green tree branches.

Section 5 – Monitoring Forest Recovery

Why is monitoring necessary?

The purpose of monitoring is to discover if tree planting actually results in the desired effects. For conservation projects, this means finding out whether or not planted trees survive and grow well and whether tree planting accelerates natural forest regeneration and biodiversity recovery, particularly by enhancing the re-establishment of additional (non-planted) tree species. Monitoring can also help to identify problems with species selection, planting techniques and/or the methods used to care for planted trees. It stimulates further experiments to continuously improve restoration projects.

What are control plots and why are they important?

Control plots are as similar as possible to planted plots *e.g.* altitude, slope, aspect, previous land use *etc.,* except that they are not planted with trees. Planted plots are then compared with control plots to determine if tree planting really does result in denser forest, with higher biodiversity than that, which would have developed by natural regeneration. If not, then more resources need not be wasted on a nursery and tree planting. Instead, efforts can be directed towards the ANR techniques described in Part 4. For fire prevention and for effective biodiversity monitoring, particularly of animals, control plots should be placed at least a few hundred metres away from planted plots.

What is the simplest way to carry out monitoring?

The simplest way to assess the effects of tree planting is to take photographs of both planted and control plots, from the same points every few months. Photographs are easier to understand than statistics of survival and growth rates. However, if you want to know which of the planted tree species act effectively as framework trees, then some trees belonging to each of the species planted must be labeled and measured at regular intervals.

How should trees be sampled for monitoring?

When large numbers of trees are planted, it may be impossible to measure them all. The minimum requirement for adequate monitoring is a sample of at least 50 individuals of each species planted. The larger the sample is, the better. Randomly select which trees to include in the sample; label them in the nursery, before transporting them to the planting site. Plant them out randomly across the site, but make sure you can find them again. Place a coloured bamboo pole by each tree to be monitored; rewrite the identification number from the tree label onto the bamboo pole with a weather-proof marker pen and draw a sketch map to help you find the sample trees in the future.

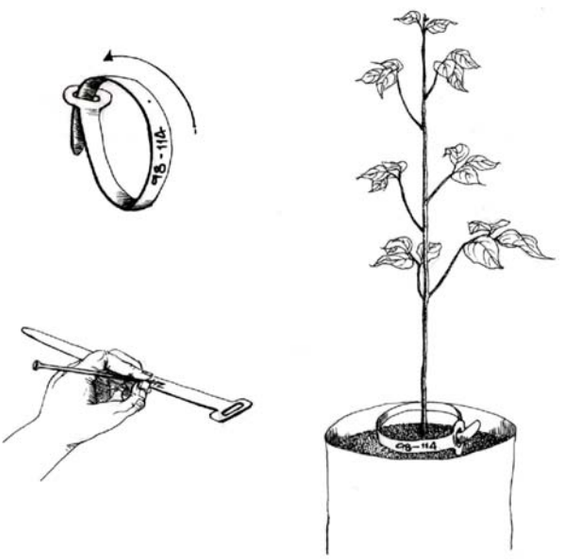
How should planted saplings be labeled?

Soft metal strips, used to bind electrical cables, available from builders' supply stores, make excellent labels for small trees. They can easily be formed into rings around tree stems. Use metal number punchers or a sharp nail to engrave an identification number on each label and bend them into a ring around the stem, above the lowest branch (if present). This will prevent the label from being buried when the tree is planted. Alternatively, drink cans can be cut up to make excellent tree labels. Cut off the top and bottom of the cans and slice the cans' walls into strips. Use a tough ball-point pen to press identification numbers into these soft metal foil strips (on the inside surface). The strips can be formed into loose rings around sapling stems.

Keeping labels in position, on rapidly growing, trees is difficult. As trees grow, their expanding trunks push off labels. If monitoring is carried out frequently, you will be able to re-position or re-place labels, before they are lost.

Once trees have developed a girth of 10 cm or more, more permanent labels can be nailed to their trunks, marking the girth measuring point at 1.3 m above ground (breast height).

Before planting, place metal labels around the tree stems. Make sure they do not get buried during planting. Label numbers could include information on species, year of planting, plot number and tree number. E.g. 98-114 07-3 could mean the 114th individual of species number 98 planted in plot 3 in the year 2007. Keep accurate records of your numbering system.



Use 5-cm-long, galvanized nails, with flat heads. Hammer only about 1/3 of the nail length into the trunk to allow room for tree growth. Metal foil from drinks cans, cut into large squares, so that identification numbers can be read from a distance, make excellent labels for larger trees.

When should measurements be made?

Measure the trees 1-2 weeks after planting, to provide baseline data for growth calculations and to assess immediate mortality, due to transplantation shock and rough handling during the planting process. After that, monitor them annually at the end of each rainy season. Additional monitoring at the end of the dry season can provide more detailed information about when and why trees die.

However, the most important monitoring event is at the end of the second rainy season after planting, when field performance data can be used to quantify how closely each species planted conforms to framework species standards (see Part 5, Section 3). Therefore, even if no other monitoring can be carried out, at least monitor two weeks after planting and at the end of the second rainy season after planting.

To monitor tree performance, work in pairs, with one partner taking measurements and the other recording data on pre-prepared record sheets. One pair can collect data on up to 400 trees per day. Prepare record sheets in advance, including a list of the identification numbers of all labeled trees planted. Take along the sketch maps, made when the labeled trees were planted, to help you find them. In addition, take a copy of the data collected during the previous monitoring session. This can help you sort out tree identification problems, especially for trees that may have lost their labels.

Monitoring Planted Trees

Measure the height of planted trees from the root collar to the highest meristem (growing point).

Measure crown width at the widest point, to assess canopy closure and site "recapture" .

What measurements should be made?

Rapid monitoring can involve simple counts of surviving vs. dead trees. More detailed monitoring involves measuring tree height and/or girth (for calculation of growth rate), crown width and health.

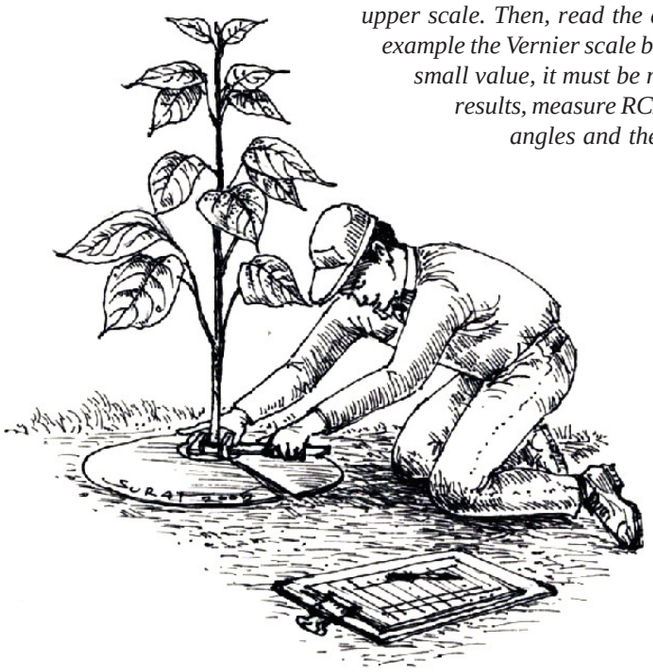
In the first year or two after planting, tree heights can be measured with 1.5-m tape measures mounted on poles. Measure tree height from the root collar to the highest meristem (newest leaf) For taller trees, telescopic measuring poles can be used to measure trees up to 10 m tall. These poles are commercially manufactured but very difficult to obtain in Thailand, so try to make your own. If you want to continue monitoring the trees after they have grown tall, measurements of girth at breast height (GBH) are easier to make and can be used to calculate tree growth rates.

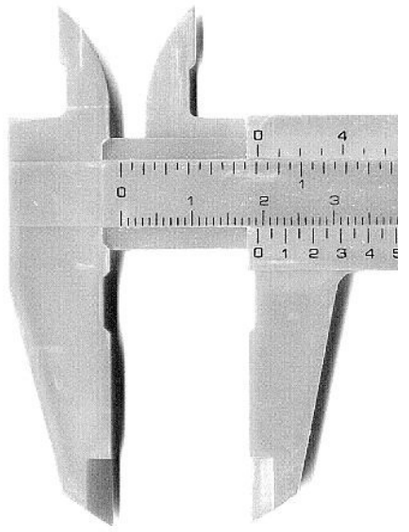
Using height to calculate tree growth can sometimes be unreliable, since shoots can occasionally be damaged or die back, resulting in negative growth rates, even though the tree may be growing vigorously. Consequently, measurements of root collar diameter (RCD) or GBH often provide a more stable assessment of tree growth. For small trees, use callipers with a Vernier scale to measure RCD at the widest point. Once a tree has grown tall enough to develop a GBH of 10 cm, measure both the RCD and the GBH the first time and only GBH thereafter.

Suppression of weed growth (an important framework characteristic) can also be quantified. Measuring crown width and using a scoring system for weed cover can help determine to what extent each tree species contributes to site "recapture". Use tape measures to measure the width of tree crowns at their widest point. Imagine a circle about 1 metre in diameter around the base of each tree. Score 3 if weed cover is dense over the whole circle; 2 if weed cover and leaf litter cover are both moderate; 1 if only a few weeds grow in the circle and 0 for no (or almost no) weeds. Do this before weeding is due to be carried out.

Measuring RCD

Callipers with a Vernier scale are available in most stationary stores.Use them to measure root collar diameter (RCD), at the widest point. At the zero mark on the lower sliding scale, read number of millimetres diameter on the upper scale. For the decimal point, look for the point at which the division marks on the upper scale are exactly alligned with the division marks on the upper scale. Then, read the decimal point off the lower scale. For example the Vernier scale below reads 19.3 mm. Because RCD is a small value, it must be measured with high accuracy. For best results, measure RCD twice by turning the callipers at right angles and then use the average reading.



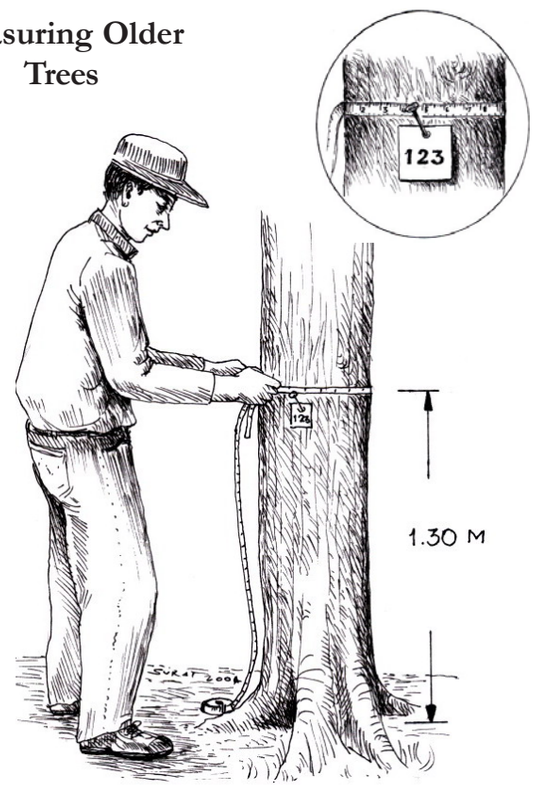


What about tree health?

Recording the health of the planted trees, each time they are inspected, can yield useful information about the vigour and resilience of each species planted to damaging factors such as fire or cattle browsing. For quantitative analysis, assign a simple health score to each tree, but descriptive notes should also be made about any particular health problems observed.

A simple scale of 0 to 3 is usually sufficient to record overall health. Score zero if the tree appears to be dead. Several framework tree species are deciduous, so don't confuse a deciduous tree with no leaves in the dry season with a dead one. Do not stop monitoring trees just because they score zero on one occasion. Many trees, which appear dead above ground, may still have living roots, from which they may subsequently re-sprout new shoots. Score 1 if a tree is nearly dead (few leaves, most leaves discoloured, severe insect damage *etc.*). Score of 2 for trees showing some signs of damage but retaining some healthy foliage. Score 3 for trees in perfect or nearly perfect health.

Measuring Older Trees



Once trees have grown large, subsequent performance monitoring can be based on increases in girth at breast height (GBH).

How should data be analysed?[1]

Compare performance among tree species planted to determine which ones function well as framework species, especially at the end of the 2nd rainy season after planting (Part 5, Section 3). To select and perform appropriate statistical tests using the Excell spreadsheet computer program (see Dytham, 1999). Calculate the per cent survival of each species as:

$$\frac{\text{no. labeled trees surviving}}{\text{no. labeled trees planted}} \times 100$$

To show significant differences in survival among species, use a Chi Squared test. Calculate mean tree height and RCD for each species Then, use ANOVA to show significant size differences among the species. In addition, you could calculate relative growth rates (RGR) for each surviving labeled tree:

$$\frac{\ln H \text{ (18 months)} - \ln H \text{ (at planting)}}{\text{No. days between measurements}} \times 36{,}500$$

...where ln H = natural logarithm of tree height (cm). RGR is an estimated annual percentage increase in size. It takes account of differences in the orignal sizes of the trees planted, so it can be used to compare trees that were larger at planting time with those that were smaller. Compare mean values of RGR, among species by ANOVA. The same formula can be used for RCD and crown width.

How should other aspects of forest restoration be monitored?

Inspect planted plots often and record the ages at which each planted tree species starts to flower, fruit or provide other wildlife resources (*e.g.* bird nest sites). Record animals seen (or their signs), especially seed-dispersers. Once canopy closure occurs, survey both planted and control plots for naturally establishing tree seedlings or saplings. Identify and label them and monitor their survival and growth. A similar survey just before planting provides a baseline, against which to assess changes over time.

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[1]For help with data analysis or to obtain spreadsheets for these calculations, contact FORRU-CMU (page 200).