Food and Agriculture Organization of the United Nations

RESTORING FOREST LANDSCAPES THROUGH ASSISTED NATURAL REGENERATION (ANR)

A practical manual

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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This publication is largely based on assisted natural regeneration (ANR) field manuals drafted by Patrick Dugan (Bagong Pagasa Foundation, the Philippines) and Stephen Elliot (Forest Restoration Research Unit [FORRU] Chiang Mai University) developed under an FAO-funded regional project on promoting the application of ANR. Kenichi Shono, Zhe Kong and Maria Paula Sarigumba provided the editing. FAO appreciates the support of partners and government officials who have worked together with FAO in promoting ANR, and these experiences are reflected in this manual. Patrick Durst, former Senior Forestry Officer for the FAO Regional Office for Asia and the Pacific, has been a long-time proponent of ANR and has done much to promote the application of ANR in the Asia-Pacific region.

1. Introduction

Background

There are numerous global, regional, national and even subnational targets for forest area and forest restoration. At the global level, these include the Bonn Challenge, the Aichi Target 15 of the Convention on Biological Diversity (CBD), the New York Declaration on Forests and Target 15.3 of the Sustainable Development Goals (SDGs). In Asia, the Asia-Pacific Economic Cooperation (APEC) has adopted an aspirational goal of increasing forest cover in the region by at least 20 million hectares by 2020, and the Strategic Plan of Action for ASEAN Cooperation on Forestry (2016-2025) includes 'Increase of Forest Resource Base' within its Action Programme. Furthermore, nationally determined contributions (NDCs) under the Paris Agreement include increase in forest cover for many Asia-Pacific countries. Furthermore, nationally determined contributions (NDCs) under the Paris Agreement include increase in forest cover for many Asia-Pacific countries (Chokkalingam *et al.* 2018).

In light of these global targets and emerging ambitious national commitments, it is imperative to develop low-cost strategies and techniques for landscape restoration. The most widely used restoration strategies involving planting of tree seedlings are often costly and their application for restoring vast expanses of degraded forest lands in the region may be limited.

Case studies and experiences with natural regeneration from the region have shown that it significantly reduces the cost of restoration in areas that meet certain conditions. Native species that are adapted to the prevailing conditions re-establish on their own with some assistance, achieving accelerated growth in accordance with natural succession, leading to the recovery of native ecosystems. Restoration strategies based on natural regeneration also provide low-cost opportunities for conserving biodiversity and enhancing ecosystem services, including carbon sequestration and watershed protection (Figure 1).

Despite these economic and environmental advantages, natural regeneration is often overlooked for various reasons when restoration policies and programmes are designed. These reasons include: not recognizing natural regeneration as a viable restoration option; perverse incentives that favor the clearing of young secondary growth for plantation development or other land uses; lack of institutional support by government agencies and other organizations; unclear tenure and property rights;

lack of incentives for local communities; and uncertainty about the restoration processes and outcomes.

Figure 1. Natural regeneration can reduce the cost of restoration activities and deliver a wide range of forest products and ecosystem services that provide local to global benefits

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The manual

This manual describes procedures from almost 20 years of FAO experience with assisted natural regeneration (ANR) in the Philippines and more recently in Cambodia, Indonesia and Lao PDR. In each of these countries, the method was applied for different objectives and convincingly validated its cost effectiveness.

In the Philippines, the goal was to restore forests on denuded lands of the public domain. Through application of ANR, there was a complete conversion of grass to diverse woody vegetation within a span of six years. Indonesia applied ANR in privately owned agroforestry farms to provide favorable growing conditions for high-value economic species like cloves. Cambodia implemented the method in shrubby forests to improve growing conditions for valuable timber species. Former slash-and-burn areas in Lao PDR were completely restored to young forest within one year.

ANR has been also practiced for many decades in other countries under varied conditions, for different purposes and under different terminologies; in China it is known as the 'mountain closure' approach and in Viet Nam it is part of the national strategy to reverse forest loss. ANR has also been used in India and Sub-Saharan Africa to replenish fuelwood supply over thousands of hectares.

ANR creates a mixed-species forest as shown in Figure 2. This imitates conditions in the natural forest where many kinds of trees and plants of different ages all grow together. This is different from the appearance of forest plantations developed in conventional reforestation projects which are typically composed of only one or a few species. The mix of species and ages in ANR forest restoration avoids the dangers of monoculture, provides protection against soil erosion and facilitates rainfall infiltration into underground aquifers.

There is increasing recognition of the benefits and advantages of ANR in light of the ambitious global, regional and national forest restoration targets, and there are considerable opportunities to expand the application of ANR through various restoration-related initiatives. It is hoped that this manual can serve as a field reference in guiding the application of ANR for forest restoration.

Figure 2. Mixed-species forest established after four to five years of ANR

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2. What is natural regeneration and ANR?

ANR and its benefits

Natural regeneration is referred to by different terms including fallow vegetation, secondary forest, succession, passive restoration, regrowth, scrubland and so forth. The same process underlies these terms: following deforestation, logging, non-forest land use or natural disturbances, new forest cover can emerge – spontaneously or with human assistance – from the ecological memory of the former forest ecosystem and the surrounding landscape – from the ecological memory of the former forest ecosystem and the surrounding landscape (Chazdon *et al.* 2017).

Natural regeneration is a biological process that can be assisted and managed to increase forest cover and achieve the recovery of the native ecosystem or some of its functions. Ecological restoration relies on natural regeneration processes for achieving forest ecosystem recovery. ANR can also be a component of forest and landscape restoration, among other interventions.

In addition to enhancing resilience and supplying multiple forest products and ecosystem services, ANR can be highly effective for recovering biodiversity, species interactions and movement within landscapes. During ANR, local biodiversity is enriched by:

- Natural establishment of trees and shrubs from seeds, root sprouts, stumps or coppices;
- Regeneration of local genetic resources adapted to local soil and climate conditions; and
- Associated pollinators, herbivores and seed-dispersal agents of colonizing trees.

Many of these benefits can also be achieved using direct seeding and tree-planting approaches, but at significantly higher costs. In tropical regions, spontaneous and assisted natural regeneration is more effective than tree planting at achieving the recovery of biodiversity and forest structure. Given these advantages, prioritizing ANR in suitable areas allows limited funds, labor and seed resources to be more effectively allocated for tree seeding or planting interventions in areas where they are critically needed for restoring forest cover and supporting local livelihoods.

Principles of ANR

ANR refers to any set of interventions that aim to enhance and accelerate the natural regeneration of native forests. ANR is a simple, inexpensive and effective technique for restoring forests by removing or reducing barriers to natural succession (Shono *et al.*, 2007).

To understand ANR, it is important to note what happens in degraded and denuded lands that are not burned or otherwise disturbed. After 10 to 20 years, these lands will be covered by trees and many other plants, growing from seeds spread by birds, animals, wind and other means. The word 'assisted' in ANR simply means helping the naturally growing young trees to grow faster.

ANR accelerates the natural successional process by protecting against disturbances (from fire, stray domestic animals and humans) and by reducing competition from grasses, bushes and vines that hinders the growth of naturally regenerated trees. The same care that we apply to planted trees is applied to naturally regenerating trees. With adequate rain and good implementation, impressive ANR results are usually evident in less than three years (Figure 3).

Figure 3. ANR results after two years

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Figure 4. Naturally growing seedling hidden under the grass

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Advantages of ANR

The use of ANR in forest restoration offers several key advantages over conventional reforestation through planting. Firstly, ANR is significantly cheaper to implement as costs associated with seedling production, site preparation and planting are greatly reduced. Second, ANR takes advantage of natural successional process which ensures that the plant community that is established is well adapted to the site conditions. Lastly, the naturally regenerating plant community in the tropics typically comprises a mixture of species. Therefore, ANR results in more diverse, multilayered vegetative cover than from typical reforestation involving the planting of a limited number of species. This diversity enhances habitat quality for local wildlife and environmental stability.

Limitations of ANR

ANR acts on natural regenerants that are already present in deforested sites. Canopy cover can be achieved rapidly, but only where regenerants are present at sufficiently high densities. Most of the trees that colonize such areas are of relatively few, common, light-demanding, pioneer species, which produce seeds that are dispersed by wind or small birds. They represent only a small fraction of the tree species which grow in the pristine native forest. Where wildlife remains common, the 'assisted' trees will attract seed-dispersing animals, resulting in recruitment of late successional tree species. However, where large seed-dispersing animal species have been extirpated, planting large-seeded forest tree species will be needed if the restoration objective is to recreate a biologically diverse forest that resembles the original forest ecosystem with its full range of ecological services and products.

It is important to note, however, that ANR is not a mutually exclusive option. It is a flexible and adaptable approach that can be applied in a variety of contexts. It can be combined with enrichment planting of ecologically and/or economically valuable species to meet the specific restoration objectives. It can also be used to restore land fertility to establish an agroforest. The various restoration options available should be combined at the landscape level to balance and optimize the different land management objectives for the wider landscape.

Box 1. Origins of ANR

Although humans have long manipulated natural forest regeneration, the concept of actively promoting it to restore forest ecosystems is relatively recent. The formal concept of ANR first emerged in the Philippines in the 1980s. Since then, a long-standing partnership between the Food and Agriculture Organization of the United Nations (FAO) and the Bagong Pagasa Foundation (BPF), a small non-government organization (NGO) in the Philippines, has played a crucial role in propelling this simple concept from obscurity to the forefront of tropical forest restoration technology, has played a crucial role in propelling this simple concept from obscurity to the forefront of tropical forest restoration technology (Elliott et al. 2013).

The BPF established an early ANR project at Kandis village, Puerto Princesa, on Palawan Island, the Philippines, to restore 250 ha of the degraded water catchment that was dominated by grasses. ANR was tested both as a restoration technique and as a development tool for improving the livelihoods of 51 families. The project combined ANR to restore forest with the establishment of fruit orchards. Treatments included fire prevention, ring weeding of tree saplings and grass pressing. The pioneer trees, which grew up rapidly after the weeding treatments, fostered the regeneration of 89 forest tree species (representing 37 tree families), including many climax forest species. The forest trees were interplanted with coffee and domestic fruit trees to provide the villagers with income. After three years, a self-sustained forest ecosystem began to develop. Systematic monitoring revealed significant biodiversity recovery and soil improvement.

Although there are now many successful ANR projects in the Philippines, very little information was initially published to enable others to learn from the experiences of organizations such as the BPF. As such, FAO has funded several projects to promote ANR for forest restoration in several countries. Launched in 2006, the project 'Advancing the Application of Assisted Natural Regeneration for Effective Low-Cost Forest Restoration' created demonstration sites on three geographically different Philippine islands. The project focused on restoring forest to degraded *Imperata cylindrica* grasslands, using weed pressing to liberate shaded tree seedlings. More than 200 foresters, NGO members and community representatives were trained in ANR methods at these demonstration sites. The project concluded that the costs of ANR were approximately half those of conventional tree planting. As a result, the Philippines Department of Environment and Natural Resources (DENR) allocated US$32 million to support the implementation of ANR practices on approximately 9 000 ha. The project has generated interest and funding from the mining industry and local municipalities seeking to offset their carbon footprints. Building on the experience of the Philippines, FAO, in collaboration with the BPF, funded similar ANR trials from 2010 to 2015 in Thailand, Indonesia, Lao PDR and Cambodia to replicate and upscale ANR application for restoring forest ecosystem services in the target countries.

3. Where is ANR appropriate?

3.1 Important factors to consider

The most impressive ANR results are achieved when the technique is applied to areas dominated by grasses such as *Imperata cylindrica*. Some people may question how grasslands can be reforested without planting any trees. This is because there are often a number of naturally regenerated tree seedlings hidden beneath the grass, which can be released to restore tree cover.

When existing tree seedlings are freed from competition and protected against destruction and damage, their growth accelerates and as soon as the crowns rise above the grass, the grass eventually die out the shade cast by the trees. Under favorable soil and climatic conditions, the trees can begin to dominate the grass in two years.

There are certain ecological, socio-economic and regulatory conditions that favor forest restoration through natural regeneration. These include:

1. **Adequate density of naturally regenerated tree seedlings**. The minimum number of naturally regenerated seedlings required will vary based on their distribution, species composition, growth rates, soil fertility, rainfall and so forth. A general guide is that a minimum of around 800 natural seedlings per hectare is required for ANR to be effective. With up to 3 000 seedlings per hectare, canopy closure will occur very quickly, within a span of two to three years.
2. **Availability of seed inputs**. There should be remnant forest patches nearby that can serve as seed sources; seed dispersers are required to carry these seeds to the restoration site. Soils should not be heavily disturbed. There should be a viable seed bank in the soil.
3. **Controlling disturbances**. It is essential to prevent or at least minimize human-induced disturbances, including fires, grazing and unsustainable harvesting.
4. **Social support**. Local communities need to be interested, willing and incentivized to participate in forest restoration.
5. **Competing land uses**. The area should be not suitable for land uses that are economically more attractive.

6. **Policies and regulations.** There should be a favorable policy and regulatory environment, as well as political will, for restoration.

7. **Capacity and local support**. Local governments or civil society organizations should have the capacity and interest to provide personnel and funds for effective supervision.

If one or more of these conditions are not in place, it will be necessary to take measures to address or mitigate the negative consequences from such situations before undertaking forest restoration through ANR. In some cases, non-ANR interventions, such as restoration through planting, establishment of a monoculture forest plantation, cash crop agriculture, agroforestry and so forth may be considered more appropriate land use for particular areas within the forest landscape.

Figure 5. A potential site for ANR

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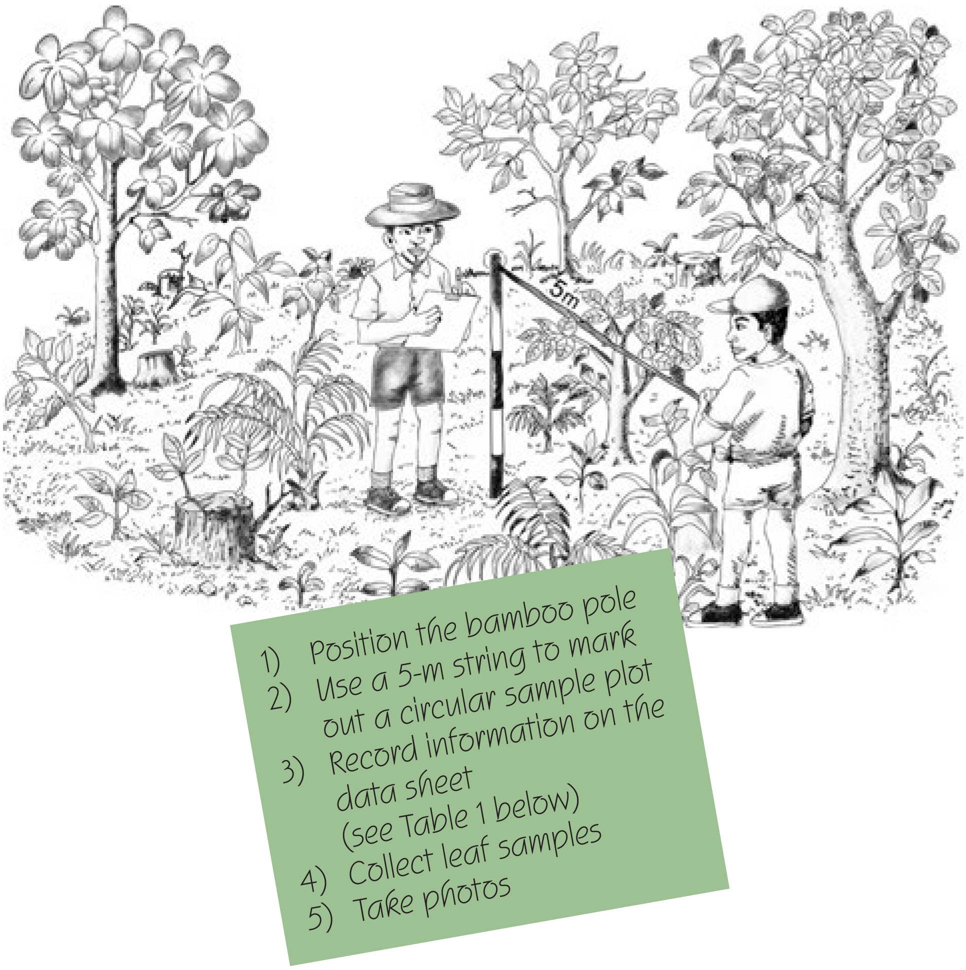
Before undertaking restoration, it is critical to identify the drivers of deforestation and forest degradation. Conversion to agriculture is the most significant direct driver of deforestation in most cases. Other direct drivers of forest degradation include overharvesting of forest products, poor harvesting practices and overgrazing. Underlying drivers include political, cultural and socio-economic factors, including unsound policies, weak governance and lack of law enforcement, unclear land tenure, rural poverty, lack of investment and financial resources, population growth, among others. While it will probably not be possible to address all direct and indirect drivers prior to implementing restoration activities, it is important to understand the dynamics of these interacting issues which operate largely outside the forest sector.

3.2 Performing a rapid site assessment

A simple site assessment can determine the existing potential for natural forest regeneration and identify the factors that may be limiting it, thus providing a basis to devise a restoration plan. The following items are needed to carry out a simple site assessment: a compass, topographic map, a GPS, a camera, bags for collecting leaf samples, a 2-metre(m)-long bamboo pole, a piece of string marked exactly 5 m from the end, a clip board with data sheets and a pencil. Invite all stakeholders (particularly local people) to participate in the site survey and begin by marking the boundaries of the site on a map and recording the GPS coordinates. Next, survey natural regeneration along a transect across the site at its widest point. Select the starting point and decide on a compass bearing to follow for the line.

At the starting point, position the bamboo pole and use the string (attached to the central pole) to mark out a circular sample plot with a radius of 5 m. If there are any signs of the presence of livestock in the sample plot (e.g. dung, hoof prints, bite marks on vegetation, etc.) tick the 'livestock' column; likewise for signs of fire (ash, or black marks at the base of woody vegetation). Ask local participants about the land-use history of the site and note down the information they provide. Estimate the percentage cover and average height of grasses and herbaceous weeds across the plot and note whether tree seedlings are strongly represented amongst the ground flora. On the data sheet record the number of 1) trees larger than 30 centimeters (cm) girth at breast height (GBH), 2) tree saplings with height of more than 1.3 m and GBH of less than 30 cm, 3) tree seedlings with height of 20 cm to 1.3 m and 4) live tree stumps (with green shoots). Collect leaf samples from each of the tree species found and place them in a plastic bag. Finally take photos, looking due north, south, east and west from the center pole.

Figure 6. How to sample natural regeneration



Pace out the required distance along the predetermined compass bearing to the next sample point and repeat. Use a new plastic bag for leaf samples. Survey at least 10 circles, at least 20 paces apart. If the site is large, position the sample points further apart and use more points. If the site is small and the required number of points cannot be fitted into a single transect, then use two or more lines, placed at representative locations across the site. Once you have decided on a compass bearing for the transect heading and a distance between sample points for each line, stick strictly to these rules during the survey.

At the end of the survey, find a clear space and sort through the leaf samples. Group leaves of the same species together and count the number of common tree species on the site (i.e. those represented in more than 20 percent of the circles). Ask local people for local species names and try to determine if they are pioneer or late successional species. If possible, make dried specimens (including flowers and fruits if present) and ask a botanist for their scientific names. Calculate the average number of regenerants per circle and per hectare.

Hold a short discussion session with participants to identify other factors that may impede regeneration, especially activities of local people such as fuelwood collection and burning to promote new grass growth. Also ask local people about which seed-dispersing animals are common in the area. Try to determine if seed dispersers are threatened by hunting.

The survey will show if fire prevention and livestock exclusion are necessary for ANR to work. If the survey indicates that the total number of regenerants is lower than 800 per hectare, ANR will need to be complemented by enrichment planting or consider conventional reforestation through tree planting. Above this density, the effectiveness of ANR increases. At a density of 3 000 natural regenerants per hectare or above, no supplementary tree planting will be needed to close the canopy within two rainy seasons.

Counting the number of different species of natural regeneration indicates the biodiversity already present. If tree planting is considered beneficial and cost-effective, select tree species that are not already present in the area, also considering their ecological and socio-economic values. The target should be to bring the total number of tree species to 30 or more, which, for most tropical forest ecosystems, is usually sufficient to 'kick start' biodiversity recovery.

Once the survey results have been used to decide on the restoration strategy, start to plan the required interventions, such as fire prevention and/or livestock exclusion, ring weeding, weed pressing and, if necessary, supplementary tree planting.

Different types of site require slightly different modifications of the approach. They can be broadly categorized as 1) grasslands, 2) areas dominated by brush or small trees and 3) young secondary forests or gulley forests. The following sections describe in detail how to implement ANR on grasslands and present additional considerations for the other two site types.

Table 1. Sample rapid assessment data sheet indicating sufficient levels of natural regeneration for ANR and the need for measures to control grazing and fires

Circle	Livestock signs	Fire signs	Weeds (% coverage and mean height)	No. trees (>30 cm GBH)	No. saplings (>1.3 m height)	No. seedlings (20 cm-1.3 m height)	No. live tree stumps	No. regenerants
1	Y	N	100%, 1 m	2	2	11	1	16
2	Y	Y	90%, 50 cm	1	3	8	2	14
3	N	Y	80%, 1 m	3	1	10	0	14
4	N	Y	85%, 1 m	2	3	15	0	20
5	Y	Y	100%, 1 m	2	5	12	1	20
6	Y	Y	90%, 50 cm	1	3	8	2	14
7	Y	Y	80%, 1 m	0	4	11	0	15
8	Y	N	85%, 1 m	0	3	20	1	24
9	Y	Y	80%, 1 m	3	4	11	0	18
10	N	N	85%, 1 m	2	2	20	1	25

Location, GPS	
Recorder	
Date	

Regenerants	Total no.	180
	Mean per circle *(=total no./circle no.)*	18
	Average per hecture *(=mean*127.3)*	2291

Total no. of tree species	18	Pioneer	16
		Climax	2

Figure 7. A target site for ANR

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Annual fires prevent natural regeneration at this site. Protection from fire and grazing should result in forest regrowth

4. Basic ANR procedures

The following basic procedures are applied in restoring forests via ANR:

1) Marking regenerants
2) Liberating regenerants
3) Suppressing grass
4) Controlling disturbances
5) Enrichment planting
6) Maintenance and protection

4.1 Marking regenerants

After the restoration site has been identified and its boundaries have been demarcated, walk through it and look for woody plants amongst the grass. Larger ones can be spotted immediately. Mark their positions with bamboo stakes. At the same time, look under the grass to locate and mark the smaller tree seedlings. Do not cut the stakes, used for marking, from tree saplings in the area. The stakes are only temporary, so if bamboo is not available, you can use dried stalks of cane grasses such as *Saccharum spontaneum* or other flimsy materials. They do not have to be made from durable wood or other strong materials. A dab of paint on the end (use a spray can) makes the stakes easier to spot amongst the grass.

If the restoration site has not been burned or disturbed for more than a year, hundreds (sometimes thousands) of regenerants may be growing underneath the grass. So the decision on what and how many to mark depends on:

1) **Intended purpose**. If the area is being rehabilitated for timber production, mark the species of the proposed final crops that are clearly emerging above the grass. Additionally, consider their spacing, particularly if there is an intention or a need to intercrop with other commercial trees. If protection is the main aim, additionally mark even those seedlings that are growing below the tops of the grass. To maximize biodiversity, prioritize marking regeneration of later successional species over densely growing seedlings of pioneers.

2) **Budgetary and time constraints**. Locating and marking regenerants can be tedious and time-consuming. Thus it is best to plan how long it will take to complete this work. Therefore, if you are a project manager, you should have a good idea on the workload and capacity of the field workers. Normally, in moderately sloping terrain, one worker can complete locating and marking 400 to 500 spots in 1 hectare within eight hours. Remember to include the time you need to collect stakes for marking.

Figure 8. Marking of wildlings

4.2 Liberating regenerants

The next step is ring-weeding to remove competing non-woody species from around the marked regenerants. Do not slash weeds with machetes or weed whackers. Uproot the weeds with hoes or other hand tools, within a circle of 50-cm radius from around the base of all natural seedlings and saplings. Close to small seedlings, hand-pull weeds (wear gloves), because hand tools may damage tree seedling roots. Make sure weed roots are exposed to air and sunshine. Cultivate the soil around the regenerants to: 1) expose seeds and roots of other undesired species; and 2) make it easier for fertilizer (if used) to penetrate towards the roots of the marked plant. Then, lay a thick mulch of cut weeds around each seedling and sapling, leaving a gap of at least 3 cm between the mulch and the stem, as this helps to prevent fungal infection. Where cut weeds do not yield a sufficient mass of mulching material, considering using corrugated cardboard, rice straw leaflitter or other materials as mulch.

Ring weeding should be implemented as often as necessary until the regenerants are tall enough to shade out competing undesired vegetation. In most cases, ring weeding should be done at least four times during the first year, and three times during the second and third years. After year three, the regenerants should be tall enough to shade out the competing vegetation without further assistance.

Figure 9. Ring weeding

4.3 Suppressing grass and other weeds

The next job is to suppress the grasses (particularly *Imperata cylindrica* and *Saccharum spontaneum*) and other weeds between the ring-weeded regenerants to further reduce competition and the risk of fire. We recommend 'pressing' or 'lodging' the weeds instead of slashing them as cutting tends to stimulate faster regrowth of the grass.

Lodging or pressing is done with a wooden board approximately 15 to 30 cm wide and 1 to 1.2 m long. Attach a sturdy rope to both ends of the board, making a loop that is long enough to pass over your shoulders. Ensure that the rope is long enough for the board to lay flat on the ground when you are standing upright. Adjust the rope length according to your height by knotting the rope.

Figure 10. Lodging board

Lift the board onto the weed canopy and step on it with full body weight to fold over the stems of grasses and herbs near the base. Repeat this action, moving forward in short steps. The weight of the plants should keep them bent down. This is particularly effective where the vegetation is dominated by soft grasses such as *Imperata*. If the grasses are particularly tough or when you are trying to press down bushes, turn the board onto its narrow end and use the leverage of the full length of the plank to press the vegetation down.

Pressing is best carried out when the weeds are about 1 m tall or taller as shorter plants tend to spring back up shortly after pressing. The best time to press grass is a few weeks after the start of the rainy season and before the end of the rainy season when the grass stems are softer. A simple way to test whether an area is ready for lodging, particularly for *Imperata*, is to flatten a small section and wait overnight. If the grass starts to spring back up by the morning, then wait a few more weeks before trying again. Always press the weeds in the same direction. On slopes, press grasses downhill.

Figure 11. Grass pressing with a wooden board

Pressing effectively uses the weeds' own biomass to shade and kill them. Plants in the lower layers of the pressed mass of vegetation die due to lack of light. Some plants may survive and grow back, but they do so much more slowly than if they had been slashed. Therefore, pressing does not have to be repeated as often as slashing. The pressed vegetation suppresses germination of weed seeds by blocking light. It also protects the soil surface from erosion, reduces evaporation of moisture from the soil and adds nutrients to the soil as the lower layers begin to decompose. Weed pressing opens up the restoration site, making it easier to move around and work with the young trees.

Pressing also helps to reduce the severity of fires. Pressed plants are much less flammable than erect ones due to lack of air circulation within the pressed mass of vegetation. Flame height is lower in pressed grass, so tree crowns are less likely to be scorched. If done properly, the beneficial effects of pressing can last up to three or four months.

Another variation in pressing is recommended when working on steep slopes. Instead of controlling the board with a rope passing over the shoulders, it is advisable to use a shorter board with handles attached on the ends. The main reason for using a short

Figure 12. Lodging board used for steep slopes

pressboard on steep slopes is to help maintain footing and balance. In addition to enabling good control of the lodging board, the handles also serve as 'walking sticks' to prevent workers from slipping and falling. This precaution is especially important during rainy weather when slopes are slippery.

Figure 13. ANR site after grass pressing

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4.4 Controlling disturbances

Protecting the regenerants from fire, browsing by livestock and chopping by humans is vital for the success of ANR. All the work done to liberate regenerants is rendered useless if the regenerants cannot be protected from such damages. As already mentioned above, grass pressing (Step 3) already reduces the risk of fire damage to the regenerants, but additional measures are also necessary.

Preventing fires

Most fires are human-induced, so the best way to prevent fires is to make sure that communities living in the vicinity support the ANR project and understand the need to prevent the occurrence of fires. However, despite all the effort that may be put into raising awareness of fire prevention among local communities, fire remains the most common cause of forest restoration failure. Most local forest authorities have fire suppression units, but they have inadequate resources and limited ability to suppress fires in remote areas, so local, community-based fire prevention initiatives are often the most effective. Such initiatives should include constructing firebreaks and conducting fire patrols to detect and extinguish fires that start before they spread over larger areas.

Establishing firebreaks

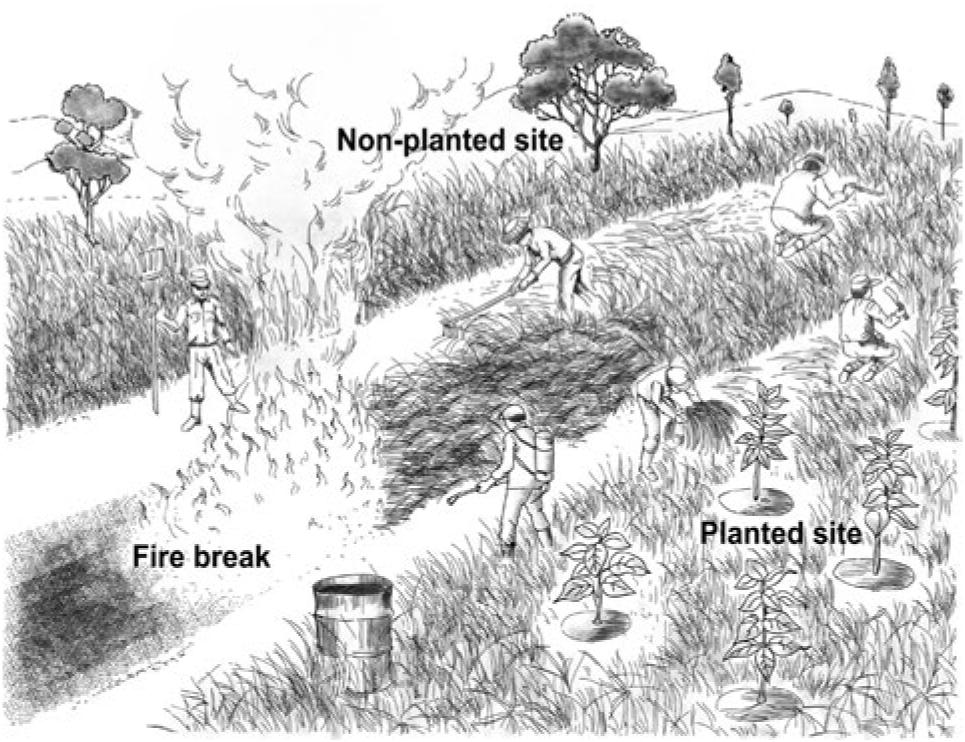
Firebreaks are strips of land that are cleared of combustible vegetation to prevent the spread of fire. The most important materials to remove are grasses such as *Imperata cylindrica* that dry up during the hot season and easily catch fire. Firebreaks are effective at blocking moderate ground fires. Piling cut grass along the contour helps to reduce the speed and force of rainwater running down the slope thus minimizing soil erosion.

To establish effective firebreaks, firstly cut them along the entire boundary of an ANR site by removing grasses and other non-tree vegetation by slashing with a machete followed by hoeing. Firebreaks should also be established along boundaries of blocks established within a site. Block sizes should be determined depending on terrain, types of vegetation, amount of volatile material and accessibility (for management and supervision). Fires in flatter areas tend to spread less quickly than on slopes so blocks can be larger. Logically, blocks should be smaller where there is more flammable material. Generally, 4 ha (an area of 200 x 200 m) is a practical size for a block, which could be adjusted to 1 ha in steep areas or up to 6 to 7 ha on relatively flat areas. Blocks do not have to have a regular shape. Block boundaries can run along ravines and ridges. Foot trails that are used by workers to access different parts of an ANR project area can also be converted to firebreaks by removing volatile material (i.e. grass) within and on both sides of the trail.

Experience has shown that firebreaks should be at least 6 to 8 m wide. It is vital to remove all volatile material, particularly grass, within the firebreak. The size of blocks and the widths of firebreaks also depend on the cost of establishment and the amount of funds or voluntary support available. Wider firebreaks and smaller block sizes are always better for reducing the risk of fires and containing fires that do occur. Logically, firebreaks should be established before the onset of dry seasons.

In addition to manually removing grasses and other vegetation, controlled burning (prescribed fire) can be used to establish firebreaks provided that sufficient equipment, tools and people trained in fire management are available, and that such use of controlled burning is legally permitted.

Figure 14. Use of controlled burning to establish a firebreak



Slashing must be followed by either digging out the remaining bunches of grass manually (grubbing) or hoeing. In addition to hoeing and/or grubbing, spraying with systemic herbicides (e.g. glyphosate-based chemicals) is an option for controlling grass regrowth, although the benefits must be carefully weighed against potential environmental damage.

Maintaining the firebreaks

It is important to prevent the regrowth of fire-prone grasses within firebreaks. For this reason, clearing by slashing, coupled with grubbing and/or hoeing has to be repeated periodically whenever needed. In most cases, firebreaks should be recleared not less than three times per year. However, fewer reclearings may be needed if grass regrowth is controlled with herbicides. It is particularly important to complete reclearing before the beginning of the dry season when the fire risk is greater.

Figure 15. Firebreaks established along ridges

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Figure 16. Well-maintained firebreak

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One strategy that can help to ensure sustained maintenance, and at the same time reduce costs, is to encourage local residents to plant food crops in the firebreaks. In this way, local communities have strong motivation for preventing fire from entering an ANR area. The food they harvest can supplement their diets or be sold for income. Depending on soil conditions, rainfall and community preference, many different crops can be grown successfully in firebreaks. Some of the more popular ones include taro (*Colocasia esculenta*), pigeon pea (*Cajanus cajan*), pineapple (*Ananas comosus*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), ginger (*Zingiber officinale*) and bananas (*Musa* sp.). Food crops to be planted should be succulent and green as not to become fire hazards.

Figure 17. Firebreak planted with crops

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Controlling livestock

Cattle, goats, sheep and other livestock can cause ANR failure by browsing on the regenerants, but they can also help to control weed growth. Ultimately, the decision to exclude livestock from the restoration site or to reduce the number of livestock depends on careful consideration of their economic value to the community and their potential to play a useful role in forest restoration, balanced against any damaging effects they have on emerging trees.

Livestock can have beneficial effects on ANR provided that the stocking density is low and the foliage of desired tree species is unpalatable. But even in such circumstances, livestock can reduce tree species richness in restored forest sites by selective browsing. The impact of livestock can be managed by tethering animals in the field to restrict their movements or by removing them altogether. Fences can be erected to exclude livestock during the early stages of ANR, but such fences must be maintained until the tree crowns have grown beyond the reach of livestock. Another solution is to cut the grass and fodder from ANR sites and carry them to the livestock. Not only does this feed the livestock without damaging the regenerants, it also encourages effective weeding of forest plots. In, Indonesia this technique is used for goat rearing in sheds. The goat dung is returned to the restoration site as fertilizer for the regenerating trees.

Figure 18. A barbed wire fence that excludes cattle results in quick recovery of vegetation in Sri Lanka

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4.5 Enrichment planting

ANR and enrichment planting should not be viewed as mutually exclusive alternatives for forest restoration (FORRU 2005). Even on sites with abundant natural regeneration, there may be patches that do not have enough wildlings to establish tree canopy cover within the desired time frame. It may also be desirable to conduct enrichment planting to complement natural regeneration for various reasons, including to restore economically, ecologically or socially valuable species. It is likely that the success and quality of forest restoration through ANR will be enhanced through some form of enrichment planting.

Enrichment planting is recommended where: 1) canopy closure does not occur due to low density of natural regenerants; and/or 2) desired tree species are not present amongst the natural regenerants. If the remnant forest is far from the ANR site and seed-dispersing animals are not present in sufficient numbers, enrichment planting may be needed to bring back the full complement of late successional forest tree species. In production forests, tree planting may be needed to increase the density of commercially valuable tree species.

Enrichment planting can be carried out during the initial stage of ANR application or after three to four years of ANR implementation based on the level of canopy closure and the tree species present; the costs and benefits of enrichment planting to improve the ecosystem should also be considered.

Direct seeding

Direct seeding involves: 1) collecting seeds from native trees in nearby remnant forest and if necessary storing them until sowing; 2) sowing them in the ANR site at the optimal time of year for seed germination; and 3) manipulating field conditions to maximize germination. The method is inexpensive because there are no tree nursery costs. Transporting seeds to the restoration site is obviously easier and cheaper than trucking in containerized tree seedlings, so the method is particularly suitable for less accessible sites.

In nature, a very low percentage of dispersed tree seeds germinate and even fewer seedlings survive to become mature trees. The same is true for direct seeding. The biggest threats to directly sown seeds and seedlings are: 1) desiccation; 2) seed predation, particularly by ants and rodents; and 3) competition from herbaceous weeds. The problem of desiccation can be overcome by selecting tree species with seeds that are tolerant or resistant to desiccation (i.e. those with thick seed coats) and by burying seeds or laying mulch over the seeding points. Burying can also reduce seed predation by making the seeds more difficult to find. Any carnivores that prey on rodents (e.g. raptors or wild cats) should be regarded as valuable assets on ANR sites. Preventing the hunting of such animals can help to control rodent populations and reduce seed predation. Seedlings germinating from seeds are tiny, so weeding around the seeding points is especially important and it must be carried out with extra care.

Leguminous trees are most commonly reported as being suitable for direct seeding. Legume seeds typically have tough, smooth seed coats, making them resistant to desiccation and predation. The nitrogen-fixing capability of many legume species can give them a competitive advantage over weeds. With the disappearance of large, vertebrate seed-dispersers over much of their former ranges, direct seeding may be the only way that the large seeds of late successional tree species can reach restoration sites.

To implement direct seeding, collect seeds of the desired tree species at the beginning of the rainy season. Dig out weeds in 'seeding spots', approximately 30 cm across, spaced about 1.5 to 2 m away from the nearest natural regenerant. Dig a small hole in the soil and loosely fill it with forest soil. This ensures that beneficial symbiotic micro-organisms (e.g. mycorrhizal fungi) are present when the seed germinates. Press several seeds into each hole, to a depth of about twice the diameter of the seed and cover with more forest soil. Lay mulching material, such as the pulled weeds, around the seeding spots to suppress further weed growth. During the first two rainy seasons after seeding, pull weeds by hand from the seeding spots as required. If multiple seedlings grow at any seeding point, remove the smaller, weaker ones, so that they do not compete with the largest seedling. Experiment to determine the most successful species and techniques for direct seeding at any particular site.

Planting with cuttings

Some species suitable for enrichment planting can be successfully planted with cuttings. Timing is important in this regard. For example, *Gliricidia sepium*, which is normally planted via cuttings, will often rot if planted at the height of the rainy season. Cuttings of this species should be planted during the closing months of the rainy season when some dry days may be expected, or during the first month of the rainy season when there will still be some sunny days. On the other hand, survival rates are higher for mulberry (*Morus alba*), another species usually planted via cuttings, if planted during rainy months. Additional species sometimes planted via cuttings include *Pterocarpus indicus*, *P. macrocarpa* and species of *Ficus*.

No matter what species are planted via cuttings, it is important to soak the cuttings in root hormones prior to planting. This significantly increases chances for success. Another important task is the preparation of planting spots. Many attempts to grow trees from cuttings fail because the cuttings are simply pushed into the ground. The proper procedure is to dig a hole, place the cutting in the hole and press the soil firmly around the cutting. Planting holes for cuttings should be about 15 cm deep. With good timing, rooting hormone treatment and proper planting in holes, the average survival rate for cuttings is usually around 50 percent.

Planting with potted seedlings

Potted seedlings can also be used for enrichment planting in ANR. However, the cost of seedlings (or the nursery costs in raising seedlings), transport and labor in land preparation and planting are often expensive, partially discounting the cost advantages of ANR. Nonetheless, there can be some benefits of planting potted seedlings in an ANR project, especially if the seedlings can be provided at low cost or free of charge through partnerships with government agencies and/or the private sector. Planting can be organized as a volunteer activity involving civic groups, local government officers or other members of society; it helps to raise awareness on ANR and the benefits of forest restoration.

4.6 Maintenance and protection

Ring weeding and weed pressing must be repeated at regular intervals until the regenerants close the canopy and naturally shade out the weeds. The frequency of such maintenance (usually three to four times per year) depends on the rainfall and how fast the weeds grow. As a rough guide, if it looks like the weeds will overtop the regenerants, carry out ring weeding and grass pressing. Firebreaks will also need to be maintained regularly, normally at least three times per year, with fire patrols by local residents carried out during the dry months.

Fertilizer

Most tree seedlings and saplings up to about 1.5 m tall will respond well to fertilizer applications, regardless of the soil fertility. Fertilizer application increases survival and accelerates growth and crown development. This brings about canopy closure and shades out weeds sooner than if no fertilizer is applied and, thus, reduces labor costs for ring weeding and weed pressing. Although chemical fertilizers can be expensive, the costs are partly offset in the long term by reduced weeding costs. In a production forest, fertilizer can also result in earlier income from commercial tree species. Organic fertilizers, such as manure, can be used as a cheaper alternative to chemical fertilizers.

Protecting seed dispersers

To ensure biodiversity recovery in ANR sites, it is just as important to protect seed-dispersing animals, as it is to protect trees. Seed dispersal from intact forest into the restoration area is essential for the return of late successional forest tree species. The hunting of seed-dispersing animals can therefore substantially reduce tree species recruitment. Simple education campaigns as well as local village rules to prevent hunting can be effective in turning hunters into conservationists.

'Assisting' the seed rain

Seed dispersal is a vital and free ecological service which ensures recolonization of ANR sites by a wide range of forest tree species. Artificial bird perches are a rapid and cheap way of attracting birds and increasing the seed rain in restoration sites. Perches are usually 2-to-3-m-high posts, with cross-bars pointing in different directions.

Figure 19. Bird perches can help attract seed dispersing birds to the restoration site

Seed rain is increased beneath such perches but seedling establishment increases only if weeding is carried out beneath the perches. Otherwise the weeds will stifle the young tree seedlings. Although artificial perches attract many birds, they do so less effectively than actual trees and shrubs, which provide the added benefit of shading out weeds, thus improving conditions for seedling establishment. Establishing the kind of structurally diverse vegetation promoted by ANR is therefore the best way to attract seed-dispersing birds and animals, but it takes time. So, in the meantime, artificial bird perches can provide a decent stop-gap measure.

5. Developing sustained social support for ANR

There are usually communities within and adjacent to denuded lands or degraded forests that depend on such areas for many of their daily needs. In almost all cases, these groups become collaborators or implementers of forest restoration projects. FAO experience in ANR implementation in Southeast Asia has shown that it is very important to first promote awareness of ANR objectives among the residents and conduct frequent formal and/or informal discussions at the village level. Such dialogues should be conducted for the whole period of project implementation or until such time that the people demonstrate strong commitment and support (e.g. by providing unpaid work). Such voluntary actions can comprise fighting fires that threaten to enter the project area or providing one day of labor within a month. If ANR is being implemented as part of a project, it is essential that community residents understand and appreciate the benefits they can expect from the project during implementation (i.e. employment) and from future results of ANR application (i.e. improved ecosystem services and economic conditions). Experience has shown that support of local leaders up to the town or district level and from local forestry officers is essential for successful ANR implementation. This is because villagers are usually familiar with and trust them.

The standard process is to first orient local leaders about the project and gain their support. In turn, they can easily convince the villagers to collaborate in implementation. A major benefit of having good support from local leaders is that they can help to solve social or political problems encountered by project implementers. Another advantage is that when project funding ends the local leaders can mobilize financial support from their own resources if the community strongly feels the need to continue ANR activities. In some instances, political influence can help access funds from as high as the national government bodies.

If ANR is being implemented individually by farmers or through their community organizations or informal work groups, ANR needs to be explained to other community residents. Their cooperation is essential for preventing fires and other disturbances that would make it difficult to implement ANR successfully.

A useful technique during project implementation is to encourage community organizations to develop their own rules in governing forests restored through ANR.

These rules specify how the restored forest will be managed in terms of benefits that can be derived, how protection and monitoring will be organized, and what disciplinary actions will be imposed on those who violate the rules. Such rules are best endorsed by higher authorities (town or district heads) and forestry agency officials. Such endorsement strengthens the feeling of responsibility by the community organizations towards the forest.

Box 2. Social support for ANR efforts in Danao, the first ANR municipality in the Philippines

Danao, an interior town of Bohol, has been declared the country's first-ever ANR municipality in the Philippines through a resolution made by the municipal council in 2008. The ANR efforts in Danao were initiated in 2006 with the main objective of effectively converting deforested lands or degraded vegetation to secondary forest with diverse plants. The efforts involved various stakeholders from the central government level to local communities, including Forest Management Bureau, DENR, local government units (district, municipality, village etc.) and local land users.

At the initial stage, the concept of ANR was not well known among the stakeholders. Therefore, a series of ANR training events was conducted, which envisioned empowering a cadre of ANR practitioners from the DENR, non-government units, the academe, research institutions, civil society organizations and other stakeholders all over the country. Stakeholders were trained and equipped with the necessary knowledge and skills to help accelerate the application of ANR and demonstrate a simple, low-cost method for improving performance and success rates in forest rehabilitation programmes.

Aided by the training events, practitioners in Danao were motivated to change their traditional strategy of restoring forests to ANR for improved water security and water quality. Local stakeholders were closely involved in ANR practices in terms of planning, decision-making as well as implementation of various on-the-ground activities, including the establishment of firebreaks, conducting patrol works, conducting ring weeding and augmentation planting. The communities were also encouraged to plant cash crops within the firebreaks to increase their short-term economic benefits. Through the ANR approach, natural regeneration of the vegetation from grassland to forest has become more apparent with the emergence of natural secondary forest species. Notable changes in plant diversity have also been observed within a span of 17 to 18 months. Apart from Danao, ANR has also been promoted throughout the Philippines, as the approach is a simple, inexpensive and effective technique for restoring forests at a large scale.

Figure 20. Supporting ANR is a family affair in Bohol

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6. ANR in degraded forests

In some areas, woody species in the form of bushes and small trees (rather than grass) already comprise the dominant vegetation. This is often the case in recently logged-over areas or sites which have not been cultivated for many years.

On such sites, if the objective is the establishment of a protection forest (e.g. for watershed protection), the only ANR interventions required will be firebreak establishment and other sustained protection against fire, livestock foraging and so forth.

If the objective of restoration is to maximize the commercial or ecological value of the stand, the following activities can be undertaken: 1) locate the desired species of tree seedlings and saplings; 2) remove competing vegetation such as vines and climbing bamboo to enhance growth; and 3) protect the area against damage by fire, stray animals and so forth. Restoring tree cover via ANR helps to prevent soil erosion, improve soil fertility and reduce soil temperature, thus promoting propagation of helpful mycorrhizae. This demonstrates that ANR can be the first step in a restoration process that has economic and social objectives, as well as environmental objectives.

As grass growth is scant in these types of areas, there is probably no need for pressing/lodging. However, ring weeding may be necessary around the regeneration of preferred species. Preferred commercial species may be fertilized if the area is intended to be a production forest. If ANR is implemented as the first phase of development in establishing timber plantations, the rates of success will improve as ANR's emphasis on fire prevention addresses one of the major causes for failure in the development of timber plantations in grasslands. In Indonesia, ANR has been successfully used as a way of creating favorable conditions for establishing agroforests (Box 3).

Because of better water supply and the low probability of burning, secondary forests containing some mature trees can often be found growing along creeks or in gullies in large denuded areas. ANR can be used to enhance these gulley forests. As the gulley forests serve as seed sources, ANR can be applied in the areas adjacent to them to gradually expand the forest into the adjacent grasslands.

Figure 21. Forest along a gully surrounded by grassland

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Box 3. ANR to establish an agroforest in Indonesia

ANR was introduced as part of agroforestry development in Paninggahan village on the slopes of Lake Singkarak watershed in West Sumatra in Indonesia in 2009.

Clove trees (*Syzygium aromaticum*) are an important source of employment and income for the residents of the village. For many years, establishment and efficient maintenance of these trees had been difficult due principally to severe competition from fire-prone *Imperata cylindrica* grass and *Lygodium* ferns, further exacerbated by erratic markets. ANR has provided the farmers with a practical, low-cost method for dealing effectively with *Imperata/Lygodium* competition while concurrently fostering the growth of indigenous trees that serve as windbreaks to protect the cloves and other interplanted crops.

With the implementation of ANR, the land became productive again and new clove trees were planted among the natural regeneration, intercropped with fruit trees and indigenous tree species. Once the newly planted clove trees began to produce, average income per farm increased from almost zero to an estimated Rp 900 000 in the first year and to over Rp 3 000 000 for the second-year harvest (USD 1.00 = Rp 14 156). Most of this income was earned on less than 0.5 ha per farmer.

With additional intercropping of economically-valuable trees, production progressively increased and as more farmers begin to apply ANR. By 2015, some 55 Paninggahan village families, with approximately 300 residents, had already benefited from ANR.

Figure 22. Agroforest developed through ANR after 3 years in Sumatra, Indonesia

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7. Monitoring

Monitoring is an essential component of any forest restoration project. Monitoring enables adaptive management based on feedback data and informs the effectiveness and impact of restoration activities implemented. There are many different approaches to monitoring depending on the objectives of the restoration activity. Monitoring approaches include: simple photograph-based monitoring; plot-based assessment of the number of tree seedlings (including natural regeneration and survival of planted seedlings) and measuring the growth rate of these trees; survey of biodiversity recovery; measurement of biomass accumulation; remote sensing monitoring of the changes in vegetation; and monitoring of other specific parameters (soil fertility, leaf litter accumulation, soil erosion, presence of wildlife species of interest, socio-economic benefits to the local community, etc.).

It is beyond the scope of this manual to cover in detail all of the available monitoring methods as these can vary widely and different methods may be combined. The basic common approaches are briefly described in the following paragraphs.

Photo point monitoring

This is the simplest monitoring approach, which can be quite effective in providing a visual documentation of changes in the condition of vegetation. Photo monitoring produces regular reliable information that can be shared easily and understood by non-experts. Photo point monitoring should start at the commencement of the project before any activities are implemented to document the baseline situation so that the project impacts can be assessed.

Sample plot-based monitoring

Sample plot measurements can be used to assess changes in the vegetation (including the growth and survival of tree seedlings, changes in dominance by weedy vegetation and plant diversity), biomass and carbon stocks, soil conditions and watershed functions. There are various different ecological survey approaches to select from depending on the parameters to be monitored, accuracy and statistical rigor required, site conditions, availability of capacity, and resources, among others. If plot-based monitoring is needed, it is recommended to work with local universities and/or government extension officers in implementing the monitoring activity.

Box 4. Photo monitoring procedures

Take photos of the vegetation at all boundary and sample unit center poles. At boundary poles, take photos looking towards the center of the study site. At sample-unit poles, take four photos, looking out from the pole roughly north, west, south and east (in that order). Take photos at other locations, which give the best possible view of the whole study site as needed but place a numbered metal pole at every photo monitoring point, for future reference. Set the camera to the widest possible zoom setting and the highest resolution. Frame each picture to include the top of the pole (showing the pole ID number) in the lower right-hand corner. Use a compass to record the direction of the photo. Keeping the top of the pole in the lower right-hand corner of the picture, gradually tilt the camera down to minimize the amount of sky in the shot, so the horizon should be near the top edge of the picture. Repeat photo-monitoring in the mid-dry and wet seasons and at annual intervals. Use the same camera with the same zoom and resolution settings for all photos. Transfer photos to a computer as soon as possible and rename the files as follows: pole reference number_date (yymmdd) e.g. B08E_120315 (boundary pole 8, facing east, taken on 15th March 2012).

Figure 23. Top of a pole showing the ID number

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Remote sensing monitoring

The recent increase in user accessibility to satellite imagery and processed outputs and the advent of Web-based remote sensing interfaces have enabled non remote sensing experts users to conduct land cover assessment with relative ease. The *Mangrove carbon estimator and monitoring guide* published by FAO and the International Union for Conservation of Nature (IUCN) (Broadhead *et al.*, 2015) describes a forest monitoring method that uses the Global Forest Watch Interactive Map. Collect Earth and SEPAL, which are open-source software developed by FAO, also offer great potential for monitoring forest restoration activities.

8. Costs and labor requirements for ANR

The ANR method is decidedly cheaper to implement than other methods based on planting of trees as the costs associated with raising seedlings in a nursery and transplanting them in the field are lowered (Shono *et al.*, 2007).

Labor is the main cost associated with ANR implementation. Normally, in moderately sloping terrain, one worker can usually complete locating and marking 400 to 500 spots in 1 ha within eight hours, not including the time needed to collect stakes for marking. For pressing weeds, one person can complete 2 000 square meters (m^2) in one day on average (five to six working days to complete 1 ha). Cutting grasses with a bladed tool can take up to 12 person-days to fully cover 1 ha, so pressing is a more efficient way of controlling the grass. Initial ring weeding takes twice as long (approximately 1 000 m^2/day), assuming 1 000 stems of marked seedlings per hectare. A team of three can therefore initially treat (pressing and ring weeding) 1 ha of land in five days. Establishment of firebreaks requires an additional 16 person-days of labor per hectare. Maintenance operations require about half of the amount of labor needed for the initial establishment.

As a guideline, Friday *et al.* (1999) estimated that 49 person-days per hectare are needed in the first year for the establishment and maintenance of firebreaks, ring weeding around seedlings and three subsequent maintenance weeding, and two applications of grass pressing. In the second and third years, it is estimated that 31 person-days of labor per hectare are required annually for the maintenance of firebreaks twice a year and ring weeding and grass pressing three times annually.

It is difficult to provide an estimate of the costs of ANR implementation as this would depend on various site- and country-specific factors. Labor costs, transportation costs, remoteness of the site, size of the area to be restored, amount of enrichment planting required, maintenance frequency, time required to achieve canopy closure and many other factors influence the overall costs of ANR.

Dugan (2011) estimated the costs of ANR implementation in the Philippines to be USD 579 using the following assumptions:

- Target sites are dominated by *Imperata cylindrica* with approximately 800 regenerants per hectare;
- 1 000 m^2 of firebreaks are required per hectare;

- Firebreaks are maintained (weeded) eight times within three years;
- There is a three-year implementation time frame; and
- There are nine pressing (lodging) cycles: 3 times/year for 3 years.

Ong (2011) estimated USD 70-100/ha for application of ANR in degraded forests in Malaysia entailing the cutting of vines and selective liberation of potential crop trees. Similar cost levels were observed during ANR project implementation in Cambodia and Lao PDR.

Both Dugan (2011) and Ong (2011) estimated the costs of restoration through planting to be around USD 1 000/ha, indicating that the cost of ANR is at least 50 percent cheaper than the conventional reforestation approach.

9. Conclusions

There is increasing recognition that an integrated landscape approach to forest restoration is necessary to guarantee a productive and socio-economically viable forest landscape in the long term. The ANR approach can be a useful intervention within the overall landscape restoration strategy as a cost-effective method of forest restoration. ANR aims to restore some of the ecological functions of the original ecosystem while not compelling a return of the modified landscape to its historically pristine state. There is currently momentum building on ANR in view of the many benefits it provides, including habitat restoration, conservation of biodiversity, watershed protection, climate change mitigation and provision of a range of products and services.

ANR follows the very simple principles of preventing recurring disturbances and assisting natural regeneration grow better. ANR can be applied under a variety of contexts for different purposes, for example to regenerate buffer-zone forests surrounding a core protected area, to restore biological corridors connecting remnant forest patches or to enhance watershed protection. ANR-restored forests can serve as multiuse areas where local communities are given access for sustainable use of the forest resources.

Considerable areas in many tropical countries remain in a degraded condition because they cannot be economically rehabilitated for agricultural use or commercial plantations. Furthermore, the high costs associated with ecological restoration through planting limit its applicability for restoring large areas of forest. ANR presents a potential solution to fill the gap, accelerating natural forest regeneration over large areas while simultaneously improving biodiversity and the social value of the landscape.

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