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Ethiopian Forestry Development

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Restoration of Degraded Forest Landscapes through Assisted Natural Regeneration: A practical manual

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List of Abbreviations

AFR	African Forest Landscape Restoration
ANR	**Assisted Natural Regeneration**
A/R	**Afforestation/Reforestation**
CBD	**Convention on Biological Diversity**
CRGE	**Climate Resilience Green Economy**
EFCCC	**Environment, Forest and Climate Change Commission**
EFD	**Ethiopian Forestry Development**
FAO	**Food and Agricultural Organization of the United Nations**
FDRE	**Federal Democratic Republic of Ethiopia**
FLR	**Forest Landscape Restoration**
GHG	**Green House Gas**
ha	**Hectare**
IUCN	**International Union for Conservation of Nature**
m	**Meter**
MEFCC	**Ministry of Environment, Forest and Climate Change**
SDGs	**Sustainable Development Goals**
WBISPP	**Woody Biomass Inventory and Strategic Planning Project**

Chapter 1: Introduction

1.1. Background

Throughout the world today, depletion of natural resources is among the major problems facing humanity. It was a significant global issue during the 20th century and will remain of high importance in the 21st century because of its adverse impact on land productivity, the environment, and its effect on food security and the quality of life (Eswaran *et al*., 2001). Deforestation and the consequent degradation of land resources, impoverishment of watersheds and disruption of ecological balance has had a serious adverse impact on the lives of rural people the world over, particularly in arid and semiarid tropics. That is why many countries are battling to overcome the challenges through rehabilitation and restoration of degraded landscapes. This challenge is highly linked to the challenges of poverty, drought and climate change. Although, rehabilitation and restoration of degraded landscapes is considered to be vital to address increasing challenges of food security, poverty, climate change impacts and biodiversity losses.

Forest landscape restoration (FLR) is being widely promoted as a solution to the global loss and degradation of the world's forests and as a contribution to sustainable development through restoring the ecological, social and economic values and functionalities of degraded landscapes. There are numerous global, regional, national and even subnational targets for forest area and forest restoration. For example at the global level, commitments including Bonn Challenge and New York Declaration on Forests as well as the Initiative **20x20** (Latin America and the Caribbean) is a country-led effort to bring 20 million hectares of land in Latin America and the Caribbean into restoration by 2020, Sustainable Development Goals; Convention on Biological Diversity (CBD) Aichi targets 15, the Convention on Biological Diversity pledge of restoring at least 15 per cent of degraded ecosystems (CBD, 2010), thereby contributing to climate-change mitigation and adaptation and to combating desertification, and the UNFCCC REDD+ goal to slow, halt and reverse forest cover and carbon loss. The African Forest Landscape Restoration Initiative through the AFR100 is one of the parallel efforts made at Pan-African level. This initiative is country-led effort to restore 100 million hectares of deforested and degraded landscapes across Africa by 2030. AFR100 is expected to accelerate restoration to enhance food security, increase climate change resilience and mitigation and combat rural poverty. These global and regional initiatives are expected to directly contribute to the Sustainable Development Goals (SDGs) and the global climate agreement.

Deforestation and land degradation in Ethiopia have a long history with spatial variation, especially in the central and northern highlands where subsistence farming and settlements have been changing landscapes for millennia. Major land cover changes resulting from improper practices are taking place on the rugged topography that characterizes most of the Ethiopian highlands, which have accelerated land degradation and soil erosion. Ethiopia lost annually 1.5 billion metric tons of top soil from the highlands by erosion, which significantly reducing its agricultural productivity and threatening food security at national level (Tadesse, 2001).

Agricultural land expansion and high dependence on biomass energy are the two most important direct drivers of deforestation and forest degradation in Ethiopia (Reusing, 1998, WBISPP, 2004). Between 2000 and 2008 alone, agricultural lands expanded by about 4 million hectare, and 80% of these new agricultural lands came from conversion of forestlands, woodlands, and shrub lands (FDRE, 2010). This degradation, often caused by deforestation, is a severe problem in Ethiopia, causing low agricultural productivity, food insecurity and rural poverty. Ethiopia's forests and forest landscapes are increasingly under threat as the growing population requires more fuel wood and agricultural products. Unless action is taken to change the current path, an area of 9 million ha of land will be degraded until 2030 (CRGE, 2011).

FAO (2000) estimate that some 50% of the highlands are significantly eroded, of which 25% are very seriously eroded, and 4% seriously eroded land have reached a point of no return. The highest average soil loss occurs on currently unproductive land with less vegetation cover that was once under cultivation. Ethiopia has made restoration opportunity mapping national wide and this study indicates about 29 million ha of land requiring restoration action (MEFCC, 2018) of which 11 million ha requires immediate response.

Over the last decades, rehabilitation of degraded lands and degraded forests has become a priority in the country's development agenda. In its strategic document, the Government of Ethiopia identified the forestry sector as one of the pillars of the green economy that the country is planning to build by 2030 (CRGE, 2011). The government also set the following major targets for the forestry sector: afforestation on 2 million ha, reforestation on 1 million ha and improved forest management of 4 million ha of natural high forests and woodlands (MEFCC, 2018). Tree-based landscape restoration contributes to the goals of the forestry pillar of "protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks" (FDRE, 2010). Through proper management of 5 million ha of natural forests and woodlands, Ethiopia hopes to achieve 50% of its total domestic greenhouse gas (GHG) emissions abatement potential by 2030. In light of global targets and emerging ambitious regional and national commitments, it is imperative to develop low-cost strategies and techniques for forest landscape rehabilitation/restoration through assisted natural regeneration.

Case studies and experiences with natural regeneration from different countries 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 (FAO, 2019). 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 the 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 favour 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.

Recognizing land degradation and deforestation as a major environmental and socio-economic problem, the government of Ethiopia has made several rehabilitation measures on degraded lands by investing heavily in restoring hundreds of thousands of hectare degraded and deforested landscape, with the support of international and bilateral agencies (Shiferaw *et al*., 2008, Mengistu *et al*., 2017).

Nevertheless, past efforts fall short of proper a technical guideline that fits to prevailing regional and local conditions. This manual therefore, provides a technical guide on the rehabilitation and/or restoration of degraded landscapes through ANR for effectiveness and implementation at grass root level in project regions.

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

Source: FAO, 2019

1.2. Definition of terms

A number of rehabilitation/restoration initiatives have been implemented in the country, with variable success, and these are an important source of knowledge that could be used to improve future restoration efforts. Many people living around degraded landscapes are locked in a vicious circle of poverty while at the same time these communities have wealth of knowledge and skills maintained for millennia. Climate variability exacerbated by climate change accelerated further degradation and challenged existing rehabilitation efforts. In the context of this manual, the following definitions are used to understand the important terms.

Assisted Natural Regeneration (ANR) is a method for enhancing the establishment of secondary forest from degraded lands and shrub vegetation by protecting and nurturing the mother trees and their wildlings inherently present in the area and/or the human protection and preservation of natural tree seedlings in forested areas ("wildlings" or natural seedlings, and sprouts).

Forest Landscape Restoration (FLR): is a planned process that aims to regain, improve & maintain ecological functionality and enhance human well-being across deforested and degraded landscapes. FLR is more than just planting trees – it requires restoring a whole landscape 'forward' to meet present and future needs and to offer multiple benefits and land uses over time. It encompass several ecosystems and land uses, as a way of enabling users to achieve trade-offs among conflicting interests and balancing social, cultural, economic and environmental benefits. Associative

Landscape: is a contiguous area, intermediate in size between an 'eco-region' and a 'site', with a specific set of ecological, cultural and socio-economic characteristics distinct from its neighbours**. Or Landscape** means the natural and physical attributes of land together with air and water which change over time and which is made known by people's evolving perceptions and associations (such as beliefs, uses, values and relationships).

A landscape includes the physical elements of geo-physically defined landforms such as mountains, hills, water bodies such as rivers, lakes, ponds and the sea, living elements of land cover including indigenous vegetation, human elements including different forms of land use, buildings, structures and associative values including spiritual, cultural or social associations (such as heritage sites).

Restoration: is the renewing and re-establishing the presumed structure, productivity and species diversity of the forest originally present at a site. The ecological processes and functions of the restored forest will closely match those of the original forest. The aim is to restore the ecosystem back to its former condition containing the original complement of plant and animal species.

Ecological Restoration: is the practice of renewing and restoring degraded, damaged, or destroyed ecosystems and habitats in the environment by active human intervention and action. Ecological restoration aims to recreate, initiate, or accelerate the recovery of an ecosystem that has been disturbed. Disturbances are environmental changes that alter ecosystem structure and function.

Active Restoration: a restoration technique that involves more costly human induced restoration processes such as afforestation/reforestation (A/R) and associated biophysical measures.

Passive Restoration: a restoration technique that involves less costly natural processes of regeneration such as area exclosures and assisted natural regeneration (ANR).

Natural regeneration: is a biological process that can be assisted and managed to increase forest and vegetation cover and achieve the recovery of the native ecosystem or some of its functions. Natural regeneration can also be a component of forest and landscape restoration, among other types of interventions, and a part of national action plans that support ecosystem restoration targets. It is the renewal of forest crops by seed sown or by coppice or root sprouts etc.

Natural regeneration (with assistance): is a forest established by natural regeneration, with deliberate silvicultural assistance from man. The source of seed, seedlings or vegetative reproduction is natural so this is a natural forest assisted by man.

Natural regeneration (without assistance): is forests established by natural regeneration without deliberate assistance from man. These included virgin forests and those regenerated by natural means.

Afforestation: is the establishment of forest plantations in areas that were not previously covered by forest and denotes a change from non-forest to forest.

Reforestation: is the process of regenerating or replanting trees, seeding or other means in areas that have been affected and destroyed by natural disturbances like wildfires, drought, and insect and disease infestations and unnatural ones like logging or unsustainable extraction of wood, mining, forest clearing for settlement and agriculture, free grazing and development etc.

Enrichment planting: is silvicultural measure to add value to poor forest stands by planting high value trees (fast-growing trees, economically important trees, high quality trees etc.) or the process by which one planting of valuable trees species in degraded forests without the elimination of valuable individuals already present. The technique is suitable for the restoration of over-exploited primary and secondary forests as it can increase total tree species richness, volume and the economic value of forests. This option is required in areas where natural regeneration is not sufficient to ensure the establishment of a new forest generation.

Exclosures: a method of rehabilitating land by protecting an area from the interference of animals and human encroachment for limited period of time, depending on site capacity and vegetation re- establishment. Or areas socially fenced from wood cutting, grazing by domestic animals and other agricultural activities with the goal of promoting natural regeneration of plants and restoration of formerly degraded lands.

A stakeholder: is any individual, social group or institution that has interest in, is directly or indirectly affected by or can influence or contribute to an issue or activity or transaction, and therefore has a natural right to participate in decisions relating to ANR.

Land degradation: a process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land. Or land degradation is the reduction in the capacity of the land to produce benefits from a particular land use under a specified form of land management. It is viewed as any change or disturbance to the land perceived to be deleterious or undesirable.

Land Rehabilitation: the process of returning the land in a given area to some degree of its former state, after some actions and process has resulted in its damage condition.

Land Restoration: is the process of ecological restoration of a site to a natural landscape and habitat, safe for humans, wildlife, and plant communities etc. Land restoration is widely acknowledged as a way of reversing degradation processes and increasing the contributions of ecosystems and landscapes to livelihoods, land productivity, environmental services and the resilience of human and natural systems. The term "restoration" covers a wide range of conservation, sustainable management and active restoration practices that increase the quality and diversity of land resources, thus enhancing ecological integrity and human well-being.

Biological Rehabilitation/Conservation Measures: a process of returning the land in a given area to some degree of its productivity through preventing interference, tree/grass planting, soil fertility improvement and moisture conservation practices. Appropriate biological measures need to be selected and integrated with water harvesting and physical SWC measures.

Physical Rehabilitation/Conservation Measures: a process of returning the land in a given area to some degree of its productivity through mechanical and /or physical conservation measures/practices, which call for the construction of some kinds of earthwork such as bunds, terraces and moisture harvesting technologies etc. They are usually needed to dispose-off excessive storm energy safely and/or to assist infiltration of soil. Physical conservation measures are not ends in themselves; they are only aids to proper land use and biological conservation measures.

Sapling: A young tree from the time when it reaches about one metre in height till the lower branches begin to fall.

Pressing grasses: is a technique that can be used in agroforestry and tree plantations as well as ANR, to help control grasses and weed between rows and beside fuel breaks.

Weeding: is the removal of weeds, and woody plants that compete for soil nutrition, water and light with the plantation. Control of competing weeds is an important part of plantation management. Nearly all plantations require some weeding during the first few years until trees are growing well, are approaching canopy closure and are of adequate size to suppress competing weeds.

Singling: It is the reduction of multiple or forked stems to a single stem to improve the tree form and quality. It is an operation done early in the life of a tree.

Thinning: is the selective extraction of pre-mature trees with the aim to create good growth conditions for trees with good potential (crop trees) and/or Thinning is designed to create more sunlight, water, and nutrition for the remaining stand while generating forest products and income.

Pruning: is a silvicultural prescription of removing branches in order to improve tree form, and wood quality.

Direct seeding: is a regeneration method of sowing seeds of the required future trees directly on the ground**.**

Promotion of natural regeneration: All measures implemented to promote the growth and establishment of natural regeneration of tree species. This can be done by opening the canopy to allow for more light to pass on to the ground, by soil aeration, cutting liana and shrub to help the germination of seeds, liberation of matured trees to trigger seed production etc.

Regeneration tree: Small trees generated from seeds of big trees or from stumps. It includes all trees that do not reach breast height (h < 1.3m) yet.

1.3. The intention of manual

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. The main objective of this manual is to propose relevant forest landscape restoration through Assisted Natural Regeneration (ANR) activities including their approaches and eventually guide future restoration efforts in project areas. It is hoped that this manual can serve as a field reference in guiding the application of ANR for forest landscape restoration and effective implementation of the technology on the ground.

1.4. Targeted users of the manual

This manual is designed for project staffs, natural resource/forestry professional’s, rural development agents, managers of forest restoration, restoration practitioners and development agencies working at various levels on rehabilitation and restoration degraded forest landscapes through Assisted Natural Regeneration technology.

Chapter 2: What are Natural Regeneration and ANR?

Assisted Natural Regeneration and its benefits

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. Natural regeneration can also be a component of forest and landscape restoration, among other types of interventions, and a part of national action plans that support ecosystem restoration such as CBD Aichi Biodiversity Target 15. ANR is most suited for areas where protection functions of forests is critical such as areas which are ecologically vulnerable, areas where conservation of biological diversity and soil and water are highly needed, among others. 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 (Chazdon *et al*., 2017).

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 and provide diverse sustainable forest products and services.

Figure 2. Mixed-species forest established after four to five years of ANR intervention Source: Tilahun, 2009 (left) & FAO, 2019 (right)

According to, Chazdon *et al.*, (2017) 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;
- 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 effort and costs. Assisted natural regeneration is more effective than tree planting at achieving the recovery of biodiversity and forest structure. Given these advantages, prioritizing assisted natural regeneration in suitable areas allows limited funds, labour and seed resources to be more effectively allocated for direct-seeding or planting interventions in areas where they are critically needed for restoring forest cover and supporting local livelihoods (Chazdon *et al*., 2017).

2.1. Principles of Assisted Natural Regeneration (ANR)

Assisted Natural Regeneration refers to any set of interventions that aim to enhance and accelerate the natural regeneration of native forests and woodlands. Assisted Natural Regeneration is used to accelerate regeneration by assisting the natural processes and it involves cutting or pressing down the weeds around existing naturally. In addition to protection efforts, new trees seedlings are planted when needed or required through enrichment planting.

ANR is a simple, low-cost forest restoration method that can effectively convert deforested lands of degraded vegetation to more productive forests. The method aims to accelerate, rather than replace, natural successional processes by removing or reducing barriers to natural forest regeneration such as soil degradation, competition with weedy species, and recurring disturbances (e.g fire, grazing, and wood harvesting). Compared to conventional reforestation methods involving planting of tree seedlings, ANR offers significant cost advantages because it reduces or eliminates the costs associated with propagating, raising, and planting seedlings (Shono *et al.,* 2007). ANR also stimulates new natural regeneration from seed from nearby natural forest. It is most effectively utilized at the landscape level in restoring the protective functions of forests such as watershed protection and soil conservation. ANR techniques are flexible and allow for the integration of various values such as timber production, biodiversity recovery, and cultivation of crops, fruit trees, and non-timber forest products in the restored forest.

To understand ANR, it is important to note what happens in degraded and denuded lands that are not burned or otherwise disturbed. After some year's exclosures from disturbance, these lands will be covered by trees and other plants, growing from seeds spread by birds, animals, wind and other means (FAO, 2019). The word **'assisted'** in ANR simply means helping the naturally growing young trees to grow faster.

Through ANR technology unsuitable microclimate is ameliorated by the accelerated growth of naturally established pioneers and seed dispersal into the site by birds, animals and wind. With adequate rain and good implementation, impressive ANR results are usually evident in a few years (Figure 3).

Figure 3. ANR site first year (left) second year (middle) & after four years of rehabilitation (right)
Source: Tigabu *et al*., 2014

Advantages of ANR

The use of ANR in forest landscape restoration has advantages over conventional reforestation through planting summarized as follows (FAO, 2003).

- ❖ ANR significantly cheaper to implement as costs associated with seedling production, site preparation and seedling planting reduced
- ❖ Plant community established by ANR is well adapted to the site conditions
- ❖ Naturally regenerating plant community typically comprises a mixture of species
- ❖ Maintains the original vegetation stand and corresponding ecosystem functions

- ❖ Maintains the integrity of the soil and minimize soil disturbance
- ❖ Promotes hydrologic integrity and biotic functions

Therefore, ANR resulted in more diverse, multi-layered vegetative cover than from conventional reforestation involving the planting of a limited number of species. This diversity enhances habitat quality for local wildlife and environmental stability.

Limitations of Assisted Natural Regeneration (ANR)

ANR acts on natural regenerate that is already present in deforested or degraded sites. There are some constraints in the application of ANR as a forest restoration strategy. These include:

- ❖ A lack of basic knowledge of ecosystem dynamics, which would facilitate the application of ANR technology, including the ecological requirements of natural regeneration species.
- ❖ Conflicting laws and regulations; insecure land and tree tenure**.** If communities are not legally allowed to own, enter, or manage their surrounding forests, then the community will not cooperate with animal prevention and maintenance for ANR.
- ❖ Inadequate extension and lack of support**.** Because ANR activities are spread throughout the year, project staff/extension agents cannot supervise all activities, and must put more responsibility in the hands of villagers.
- ❖ Forest restored through ANR will have little commercial value in terms of timber
- ❖ Most of the trees that colonize deforested/degraded areas are of relatively few, common, light-demanding, pioneer species, which produce seeds that are dispersed by wind or small birds.
- ❖ Weak policy and incentive systems associated with the need for appropriate land tenure and benefits derived from the restoration of forest diversity.

Assisted natural regeneration 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 and direct seeding of ecologically and economically valuable species to meet the specific restoration objectives.

2.2. Rationale for Using ANR and Required Conditions

ANR is most suitable for restoring areas where some level of natural succession is in progress. As a first condition, sufficient tree regeneration must be present so that their growth can be accelerated. Seedlings of pioneer tree species are often found among and below the weedy vegetation even on a seemingly weed-dominated land. The minimum required number of pre-existing seedlings to implement ANR depends on the acceptable length of time for the forest to be restored and site-specific conditions that influence the rate of forest recovery. As a general reference, a density range of 200–800 seedlings per hectare has been suggested for ANR, and it has been estimated that at least 700 seedlings/ha are needed during the early treatment period in order to achieve canopy closure within three years (Jensen & Pfeifer 1989). Supplemental planting and direct seeding can be carried out if the density of natural regeneration is not sufficient. To ensure further successional development, remnant forest should be in proximity so that there would be sufficient input of seeds.

2.3. Principles of Forest and Landscape Restoration

Forest Landscape Restoration (FLR) is the long-term process of regaining ecological functions and enhancing human well-being from deforested and degraded lands. Ultimately, FLR is the process of restoring "the goods, services and ecological processes that forests can provide at the broader landscape level as opposed to solely promoting increased tree cover at a particular location". FLR enriches more narrowly defined approaches to ecological restoration, afforestation and reforestation by focusing on a mosaic of potential land uses and restoration interventions, with an aim of bringing multiple benefits to people and nature. A forest landscape is any area that once grew or could benefit from growing trees and woody plants, which includes agricultural areas where on-farm trees could improve productivity and functionality of the landscape. FLR is not an end in itself, but a means of regaining, improving, and maintaining vital ecological and social functions, in the long-term leading to more resilient and sustainable landscapes. Forest Landscape Restoration in the tropics is structured around six principles of FLR developed by the Global Partnership on forest and landscape restoration.

1: Focus on landscapes

FLR working takes place across whole landscapes containing mosaics of land uses, not just individual sites, so trade-offs can be balanced. FLR needs to be planned and organized at the landscape scale and not in forested areas alone. It should consider the variety of existing interacting land uses and tenure and governance arrangements in the landscape.

2: Engage stakeholders and support participatory governance

Forest landscape restoration should actively engage stakeholders- including women, young people and vulnerable groups, in planning and decision-making regarding land use, restoration goals and strategies, implementation methods, benefit sharing, and monitoring, assessment and review. Active negotiation and collaboration among stakeholders for sustainable FLR is crucially important.

3: Restore multiple functions for multiple benefits: Restoring an agreed, balanced package of landscape functions, not only increasing forest cover and not trying to re-establish the forests of the past. FLR should aim to restore multiple economic, social and environmental functions in a landscape and to generate a wide range of ecosystem goods and services that equitably benefit stakeholders.

4: Maintain and enhance natural forest ecosystems within landscapes

FLR should restore dynamic forest processes related to species composition, structure, productivity, biodiversity, pollination and floral and faunal genetic diversity. FLR interventions, therefore, should aim to restore the productivity, ecosystem functions and carbon stocks of degraded tropical forests.

5: Tailor to the local context using a variety of approaches

This principle helps ensure that the planning and implementation of FLR respond to the needs of local people and ecosystems. The best way to ensure that FLR is well adapted to local conditions is for local stakeholders to be fully involved in its development, implementation, monitoring, assessment and evaluation.

6: Manage adaptively for long-term resilience

FLR is a long-term undertaking. FLR must be tailored to the local conditions prevailing at the time of commencement but be capable of adaptation to changing economic, social and environmental circumstances.

Benefits of Forest Landscape Restoration

A landscape can be regarded as the heterogeneous mosaic of different land uses (e.g. agriculture, forestry, soil protection, water supply and distribution, biodiversity conservation, pasture provision) across a large area of land or a watershed. Forested landscapes are sources of wood and non-wood products, energy, food, shelter, incomes, human well-being and many environmental services (biodiversity conservation, soil and water protection, recreational areas, carbon storage), which are often crucial for many economic sectors (food and agriculture, livestock, drinking water supply, tourism, energy and forest industry).

Chapter 3: Types of Rehabilitation Measures to support ANR

3.1. Physical conservation/rehabilitation measures

Degradation of forest landscape is often accompanied by depletion of soil fertility to support regeneration and good growth of trees. Thus, site amendment measure should be done first to benefit successful rehabilitation of severely degraded areas through Assisted Natural Regeneration.

In Ethiopia, various efforts have been applied to rehabilitate degraded landscapes through physical and biological conservation measures. The major physical SWC conservation measures implemented in degraded landscapes includes construction of different structures; hillside terraces, bench terrace, soil bund, stone and stone faced soil bunds; stone and gabion check dams, micro-basins, trenches, half moon, percolation pits, water diversion and drainage ditches and moisture harvesting technologies (Figure 4). The physical measures are mainly for soil and water conservation activities targeted to reduce surface run-off and soil erosion, conserve soil and moisture while, aiding water percolation (Shiferaw *et al.*, *2008*, Mengistu *et al.*, 2017).

Figure 4.Physial SWC structures
Source: Merga & Haftamu, 2019

3.2. Biological conservation/rehabilitation measures

Area enclosures

An area enclosure is one of the components of biological conservation/rehabilitation measures and it is practiced in all land use types where soil erosion becomes serious and the land has lost its productive potential. Enclosures are the practice of land management whereby livestock and humans are excluded from open accessing an area that is characterized by severe degradation (Tigabu *et al*., 2014).

The area enclosure should allow entrance of the native fauna and even attract seed dispersing animals in order to enhance the natural regeneration of the flora and speed up the restoration process. Furthermore, the enclosed site may require human interventions to carry out activities, such as enrichment planting, weeding, reintroduction of the native fauna, control of alien species, and so on. In other words, the enclosed area needs to be permeable to organisms that enhance the biotic community within it and human intervention may be necessary for speeding up the natural succession and enrichment of the biodiversity. The term area enclosure does not exclude permeability for selected organisms and human intervention.

The practices associated within enclosures mainly should encourage natural process while incorporating other options that are well accepted by the local people based on the observed and perceived economic and ecological impacts (Mengistu *et al*, 2017). With a proper management plan geared towards achieving an intended objective, the enclosures technology can be extended to any area where deforestation and land degradation is a problem. In closed areas, soil erosion reduced, regeneration of the environment is observed, soil fertility improved, ground water recharge increased and the downstream users are protected from soil erosion and flood hazard (Figure 5).

Figure 5. Biophysical conservation measures at ANR site

Source: IS-FSDP, 2018 (left & middle) and Haftamu, 2019 (right)

Chapter 4: Where is ANR Appropriate?

4.1. Important factors to consider

There are certain ecological, socio-economic and regulatory conditions that favour forest restoration through assisted natural regeneration (ANR). 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. As a general guide 800 natural seedlings per hectare required for ANR to be effective.

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 and 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 etc.

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 favourable policy and regulatory environment, as well as political will, for restoration.

7. Capacity and local support. Local governments should have the capacity and interest to provide support for effective implementation ANR activities.

If one or more of these conditions are not in place, it will be necessary to take measures to 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, agroforestry and other appropriate land use technologies for particular areas within the forest landscape may be considered.

4.2. Performing a rapid site assessment

A simple site assessment can determine the existing potential for assisted natural regeneration and identify the factors that may be limiting it, thus providing a basis to develop a restoration plan through ANR. Designing management plan for ANR site require field data collection and analysis of existing situation in order to identify the underlying causes of degradation, characterize the current condition of the ecosystems and identify solutions that would restore ecological structure (physical features), composition (species assemblages), and function (biological, hydrologic, chemical) where it has been degraded or lost. The field assessment may include;

1. Environmental conditions and settings: Landscape and physical components affecting ecosystem processes, e.g., flooding regime, site hydrology, soil type and conditions, and surrounding land use.

2. Ecosystem Structure: Summary of physical structure of ecosystems, e.g., closed canopy forest, forest with canopy gaps, open canopy forest, early successional forest, shrub/scrub and grassland including other land uses.

3. Vegetation Inventory and Relative Density: Dominant species present within ecological communities and relative densities across landscape unit area (densities of native, exotic, and invasive species using vegetation assessment methodology

4. Ecological Influences: Human or naturally induced ecological influences appearing to have a substantial effect on ecosystem processes: e.g., land use history, known/existing disturbance, type/extent of invasive species, animal use evidence and environmental conditions. Once the survey results have been used to decide on the restoration strategy, start to plan the required interventions, such as fire prevention and livestock exclusion, ring weeding, weed pressing, liberation cutting and tending of woody regeneration, soil and moisture conservation activities and supplementary tree planting etc. (Figure 6). If the survey indicates that the total number of regenerates is lower than 800 per hectare, ANR will need to be complemented by enrichment planting or consider conventional reforestation through tree planting (FAO, 2019). At a density of 3000 natural regenerates per hectare or above, no supplementary tree planting will be needed to close the canopy within two rainy seasons.

5. **Socio-economic condition:** Since land degradation and forest loss are closely tied with poverty and subsistence agriculture, restoration should be a strategy to improve both socio-economic and environmental conditions. Reforestation and restoration programs and projects should be built upon in depth analyses of how people live (livelihood), value, use, manage native trees and forests/plants species or protects trees (past, present and future).

Figure 6. A target site for ANR

Source: FAO, 2019 (one left), Merga, 2018 (one middle), Haftamu & Merga, 2019 (two right)

Chapter 5: Basic procedures or steps of ANR Implementation

Different technical methods are used in implementing assisted natural regeneration. The work plan should remain flexible, and the treatments are adjusted according to how the vegetation responds to interventions. A variety of technical methods are used in applying ANR, and the following basic steps can be modified according to site conditions, restoration objectives, and resource availability. The following basic steps/procedures are applied in restoring forests via ANR:

1) Clarify goals and objectives
2) Site selection and mapping
3) Identifying and marking of woody regeneration
4) Liberating and tending of woody regeneration
5) Suppressing weedy vegetation
6) Protection from disturbances
7) Maintenance and enrichment planting
8) Direct seeding/sowing
9) Developing sustainable community support for ANR

5.1. Clarify Goals and Objectives

The goals and objectives of any ANR technology are clear before it begins. ANR is a technology that may be used by farmers and communities on their own, degraded land or degraded forest area but ANR may also be promoted and supported by a regional or national program or districts addressing watershed and landscape goals. Objectives must be negotiated and agreed upon between the community and those providing technical assistance from the regions, zones, districts and/or grass root level.

5.2. Site Selection and Mapping

Selecting sites, mapping and priorities for restoration of degraded lands through ANR requires multi-stakeholder approach. This demand mapping of different land uses and identifying land use challenges and opportunities. Participatory mapping promotes interaction and helps visualize the `mental map’ of communities (Figure 7). Using maps makes it easy to indicate resource availability, to assess infrastructures and access, and even to identify social groups and relationships. It also stimulates discussion and debate among participants during land use identification and map preparation. Once a potential ANR site and area has been identified, community consultations need to be carried out to ensure that planned activities are aligned with local level situations.

Figure 7. Community planning land use with a map

Source: Dennis *et al.*, 1999

Site-species matching

There is limited knowledge of the specific ecological requirements of natural forest tree seedlings (Kartawinata *et al.,* 2001). In the absence of any information on the niche requirements of the various seedlings and saplings located in the area, it is possible to make use of local knowledge. This type of information can be obtained by means of discussions with key members of the community. Site-species matching in ANR is critical because a mismatch will result in the loss of propagules and regeneration materials. It will also result in a waste of time and money invested in the ANR sites. Several earlier studies have suggested that local people possess more knowledge concerning their local resources than is often appreciated by experts or accepted by government officials (Leach *et al.*, 1999).

This technological step will also require good information on site characteristics such as biotic agents of dispersal, soil characteristics in relation to nutrient and moisture status, light quality and quantity, temperature, rainfall, organic matter and others. The key factor to this process is to be able to characterize site quality in terms of some key edaphic, hydrologic and biotic and other abiotic conditions.

5.3. Identifying and Marking of Woody Regeneration

Once the target area is identified and its boundaries are demarcated, the site is surveyed to assess its successional status and to locate any natural woody regeneration growing above and below the weedy vegetation. The located seedlings should be clearly marked with stakes to facilitate the application of subsequent treatments and to protect them (Figure 8). To maximize biodiversity, prioritize marking regeneration of later successional species over densely growing seedlings of pioneers. The marked desired species for regeneration should be tagged, identified and measured for monitoring of the growth and survival rates.

The minimum required number of pre-existing seedlings to implement ANR depends on objective and site- specific condition. As a general rule, a density of >200 desired seedlings (>15 cm in height; counting clumps in 1 m^2 as one seedling) per hectare is suggested for ANR.

Figure 8. Identification and marking wildlings

Source: FAO, 2019 (one left), & Dennis et al., 1999 (two right)

5. 4. Liberation and Tending of Woody Regeneration

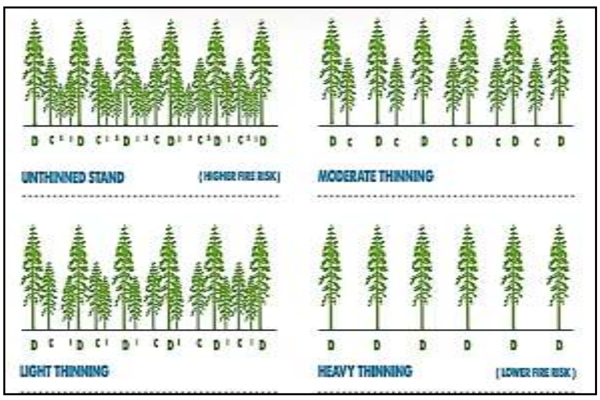
The next step is to accelerate the growth of the marked seedlings by reducing competition from the weedy species for water, nutrients and light. The initial treatment should be implemented at the onset of the rainy season so that the liberated seedlings will have the full growing season of accelerated growth. All competing vegetation such as grasses, bushes and lianas/vines within at least 0.5 m radius from around the base of all natural seedlings and saplings of the marked are removed (Figure 9). This can be done by slashing and/or ring weeding and hand cultivating or by manually digging out the competing undesired vegetation. Ring weeding should be done at least four times during the first year, and three times during the second and third years. Then, lay a thick mulch of cut weeds/grass 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.

Figure 9. Cutting lianas and ring weeding ANR site

Source: Mengistu, 2019 (one left), Dennis *et al.*, 1999 (three middle) & FAO, 2019 (one right)

Thinning and pruning

Thinning: is the removal of a number of trees from a plantation to reduce competition for light, water, nutrients and provide increased room into which the remaining trees can extend their canopies and grow faster. In some cases, clumps of woody seedlings may need to be thinned in order to liberate the largest individuals or the more desirable species. When a tree stamp have several sprouts, remove all but the 1-3 largest. Thinning consists of a series of successive felling operation for a number of times before the crop matures **(Figure 10).** Thinning increases the amount of light and space available to the remaining trees.



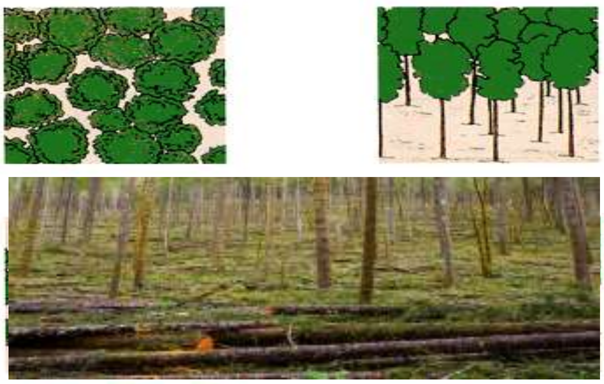


Figure 10. Thinning of saplings/trees

Source: Mohammed, 2018

Pruning has been called "one of the best, worst maintenance practices" performed on trees. Pruning is removal of undesirable branches starting from the lowest part of the tree crown to enhance better growth and yield. Pruning of trees is carried out to:

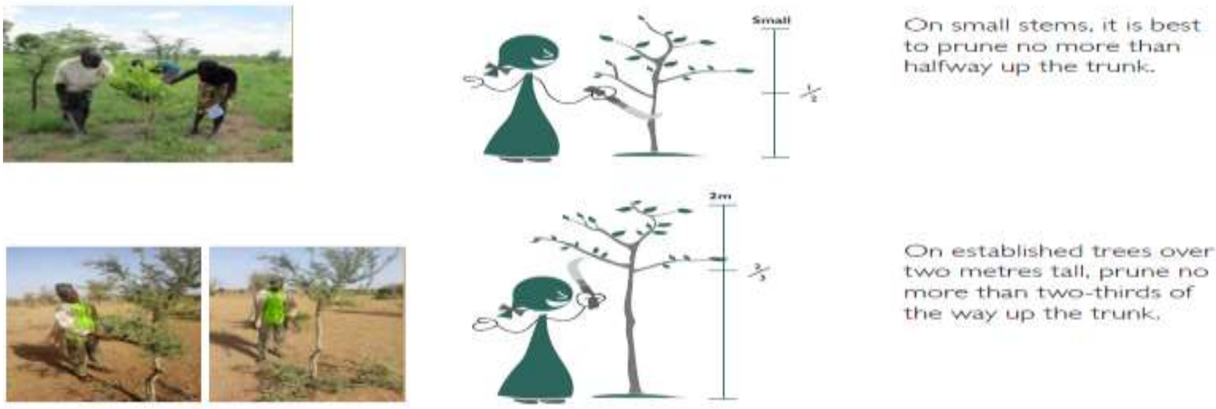
i. Reduce competition for light between trees and crops;

ii. Stimulate rapid growth for taller, straighter and more useful tree trunks;

iii. Provide early harvest of branch-wood for fuel or other use; and

iv. Enhance yields from trees because of more access to light.

To prune properly, it is important to understand both the proper techniques and how the tree responds to pruning. Prune nurse trees to gradually increase light for trees and other species that need shade when young and sun when large. As the canopy begins to close and trees compete with each other, it is worth to prune trees (Figure 11&12). If an unhealthy, branchy, crooked, or worthless tree is interfering with the growth of a healthy, straight, or valuable tree, cut or prune the unhealthy, branchy, crooked, or worthless tree. Never remove more than 25-30% of the canopy in any given year. The actual practice of pruning includes, selecting desired tree or stumps, remove the unwanted stems and side branches, and periodically return to the tree and cull emerging lower stems and prune side branches from time to time.



Identification of trees for pruning
Source: World Vision Australia, 2019

Before the equipment comes out, remember the following basic concepts:

- ❖ Identify the key components of the branch i.e. branch bark ridge and branch collar
- ❖ Each cut has the potential to change the tree forever

- ❖ Removal of branches and limbs affects the tree's ability to gather sunlight for food production
- ❖ Large limb removal can impact form and geometry, affecting stability
- ❖ Inconsiderate removal of branches can leave the tree susceptible to decline

There are three steps in standard large branch pruning:

1. The first step is to make a deep cut underneath the branch at about 30 cm up the branch

2. The second step is to move up the branch and make a second cut completely through the branch from above. This prevents snapping and tearing of the stem when the branch falls.

3. The third step is the final pruning cut which should be at a slight angle away from the main stem just outside the collar and the Branch Bark Ridge (Figure 11) Care should be taken to ensure that the bark does not tear when the remainder of the branch comes away from the main stem.

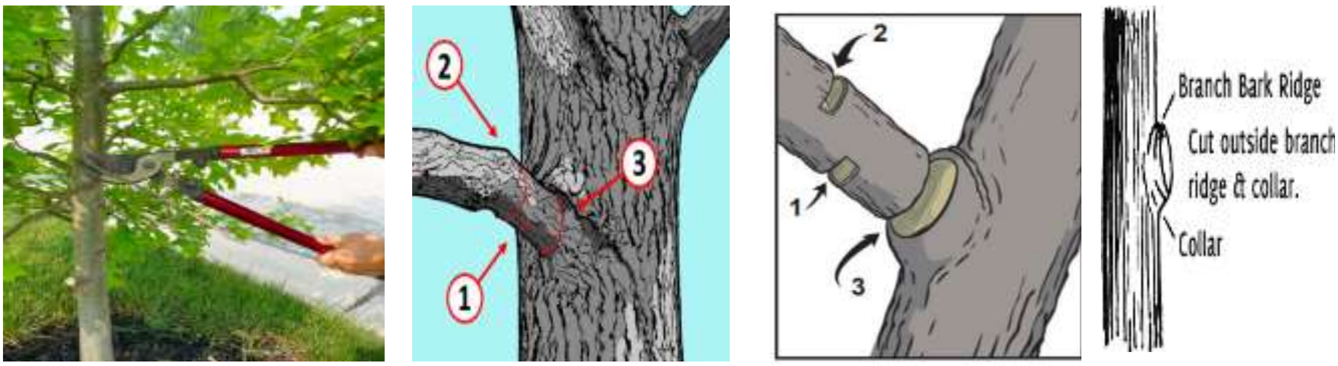


Figure 11. Identification of branches and correct methods of pruning
Source: Purcell, 2011

Figure 12. Pruned of young and matured tree branches at ANR site

Source: FAO, 2019 (left) and Merga, 2019 (middle) and Purcell, 2011(right)

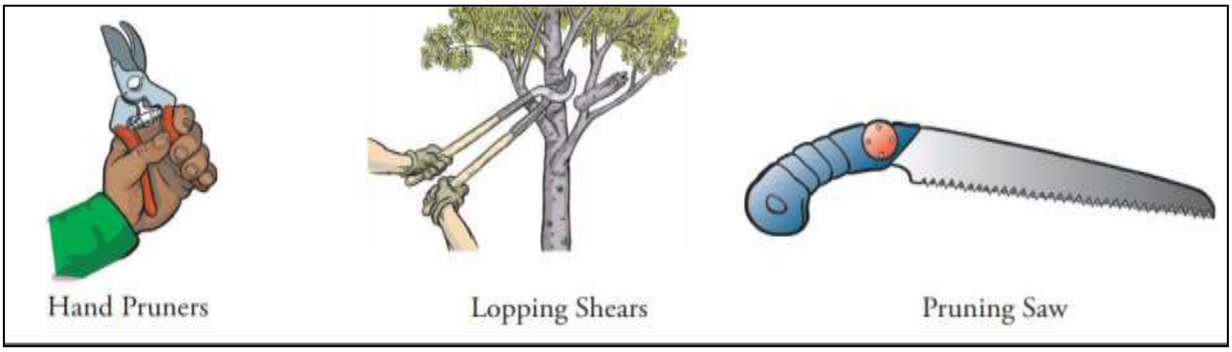


Figure 12. Pruning material

5.5. Suppressing Grass and Weedy Vegetation

All existing woody wildlings hidden in the grass should be located and clearly marked in order to protect them during grass pressing and clearing. Once the desired number of wildlings has been marked and ring weeded, the suppression of grass and other weedy vegetation throughout the site is the next critical step. In addition to reducing weed competition, it reduces fire hazard and makes movement at the site easier. Lodging or pressing is done with lightweight wooden board approximately 15 to 30 cm wide and 1 to 1.2 m long (Figure 13). A rope is fixed to each end of the board and is looped over the shoulders. 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. In this process, the grass shoots and weeds are pressed down but not broken because the breaking of the stem results in rapid tillering.

Figure 13. Grass pressing with a wooden board
Source: Shono *et al*., 2007 (left), FAO, 2019 (middle) &Dennis *et al*., 1999 (right)

Pressing or lodging 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. Pressing should be done at the beginning and end of the rainy season when the grass stems are softer. Always press the grass and weeds in the same direction (Figure 14).

Figure 14. ANR site after grass pressing

Source: FAO, 2019 (left) & Shono *et al*., 2007 (right)

5.6. Protecting the area from Disturbance

Protecting the regenerates from fire, browsing by livestock and chopping by humans and other form of disturbance is the most important for the success of ANR activities. All the work done in the area is wasted if fire destroys the liberated seedlings or if they are damaged by animals or human activities.

Preventing fire

The most critical step in ANR is protection of woody plants from fire. Since ANR is often implemented by communities rather than individual farmers, groups can be organized for fire control. Most fire are human-induced, so the best way to prevent fires is to make sure that communities living in the vicinity support the ANR site and understand the need to prevent the occurrence of fires. Establishing firebreaks around blocks of ANR-treated sites is a must, if the area is prone to fire (Figure. 15).

To establish effective fire breaks, first 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 digging or hoeing. Fire breaks should also be established along boundaries of blocks established within a site. The size of each block should be determined depending on terrain, types of vegetation, amount of volatile material and accessibility for management. 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. Firebreaks are strips of land that are cleared of combustible vegetation to prevent the spread of fire. Wider firebreaks and smaller block sizes are always better for reducing the risk of fires. The size of firebreaks should be at least 6 to 8 m wide.

Figure 15. Initial established & well maintained fire breaks

Source: FAO, 2019 (left) and Shono *et al*., 2007 (right)

5.7. Maintenance and Enrichment planting of desirable species

The maintenance of ring weeding and liberation of any additional seedlings that establish or that are newly found should be conducted every 1–1.5 months during the rainy season and every 2–3 months during the dry season (Mengistu *et al.*, 2017). The frequency of maintenance operations can be depends upon field monitoring the growth of the liberated seedlings and the density of natural woody regeneration. Enrichment planting can also be carried out to accelerate canopy closure, add useful tree species and increase stocking and floristic diversity and restore economically, ecologically or socially valuable species with in the target ANR area if the number of naturally -occurring wildlings is low < 200 per ha (Figure 16). Even after the restoration of canopy cover, large-seeded primary forest trees and rare species are un-likely to colonize naturally. If restoring floristic diversity of the original forest is one of the restoration objectives, species or functional groups of trees lacking in natural regeneration will need to be planted either at the initial treatment stage or after canopy closure depending on the ecological requirements of the 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 and benefits of enrichment planting to improve the ecosystem.

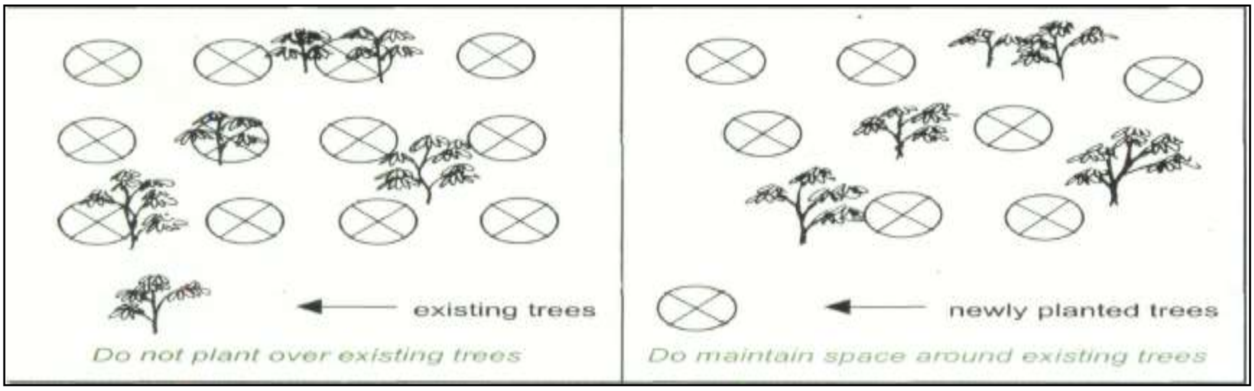


Figure 16. Enrichment planting lay out
Source: Dennis *et al*., 1999

5.8. Direct seeding

Direct seeding is a regeneration method of sowing seeds directly where the future trees, directly on the ground for rehabilitation (ANR), reforestation, afforestation or agroforestry purposes (Alem, 2017). Direct seeding of seeds of known genetic base is one of the ANR approaches to foster rehabilitation and enhance biodiversity. It is possible to establish many trees and shrubs by seeding them directly in site where, they are grow in the landscape (Figure 17). Direct seeding can considerably reduce planting and maintenance costs as compared to nursery grown seedlings. In this way the laborious task of raising nursery plants and transplanting them to the planting site is omitted. Direct sowing/seeding offers various interesting possibilities e.g. the ability to rapidly increase the area being forested or the ability to provide rural people with an inexpensive method to obtain benefits from trees (Alem, 2017).

Direct sowing/seeding is applicable in a limited number of situations, where seedlings from directly sown seeds can establish fast enough to escape fatal predation, and overcome competition from herbal weeds, grasses, climbers or other aggressive vegetation (Alem, 2017). Direct seeding/sowing is mostly applicable for fast establishing and growing species at sites with scarce vegetation. Although any desired species can be, species of seeds of trees, often exotic legumes are preferred for their nitrogen fixing and fast growing habits. The nitrogen-fixing capability of many legume species can give them a competitive advantage over weeds.

Seeds can be sown by hand and may also be placed more exactly in the ground where it is expected to grow. To implement direct seeding the following techniques are recommended.

a) Sow the seeds of the selected species into furrows of the cultivated area with hands or dig out weeds in 'seeding spots', approximately 30 cm across, spaced about 1.5 to 2 m away from the nearest natural regenerate.

b) Open furrow with fingers or hand tool to a depth of the diameter of the seed or approximately 2 times the diameter of the seed to be sown

c) Sow the seed of the species at 2-3 times the density desired at maturity (seedlings are later thinned to desired spacing when the first set of true leaves have developed)

d) Fill furrows and seeding pits with loosely forest soil and cover the sown seed with soil by pinching furrow together/seeding pits and tamp soil to assure soil-to seed contact

This ensures that beneficial symbiotic microorganisms (mycorrhizal fungi) are present when the seed germinates. Lay mulching material, around the seeding spots to suppress further weed growth.

Figure 17. Direct seeding/sowing of tree seeds for rehabilitation of degraded lands Source: (Alem, 2017)

In Ethiopia, the success of rehabilitating degraded lands through exclosures, which resulted in a dense regrowth after reducing human/livestock pressures, appeared from soil seed banks and old stumps. This success is a very good indicator for the potential of direct seeding where ever it is appropriate.

Advantages and disadvantages of direct seeding

Advantages of direct seeding

- Establishment cost is low as there are no nursery operations
- Transport cost of seed is much cheaper than seedling transportation.
- Transporting stress avoided by direct seeding

- ❖ Better root development than nursery raised seedlings
- ❖ Species can even enrich the soil if N-fixing legumes are used
- ❖ Implemented in combination with accelerated natural regeneration and conventional tree planting, direct seeding can be used to increase both the density and species richness of regenerates

Disadvantages of direct seeding

- ❖ Tree density is more difficult to control. Too high density may require early thinning, whereas too low density may require additional seeding or planting.
- ❖ Normally more seed is required to stock an area sufficiently, mainly because seeds are lost to seed-predators or erosion.
- ❖ Weed can be certainly a big problem, and it requires regular weeding

Seed dispersal

The seed produced by the trees is dispersed by the agency of wind, water, gravity, birds and animals etc. Seed dispersal agents can be advantageous (1) In escape from density-or distance-dependent seed and seedling mortality, (2) By colonization of suitable sites unpredictable in space and time, and (3) By directed dispersal to particular sites with a relatively high probability of survival.

'Assisting' the seed rain

Habitual bird perches and roosts

Seed dispersal from intact forest into the restoration and/rehabilitation area is essential for the return of late successional forest tree species. Seed dispersal is a vital and free ecological service which ensures re-colonization of ANR sites by a wide range of forest tree and other species. Artificial bird perches are a rapid and cheap way of attracting birds and increasing the seed rain in restoration sites. Many frugivorous tropical birds have lek breeding systems in which the males have display perches where they spend most of the day during the breeding season. Most of the seeds dispersed by males of these species are probably deposited in the vicinity of the lek or display perches.

Perches are usually 2 to 3 m high posts, with cross-bars pointing in different directions. Seed-dispersing agents can make ANR more effective by bringing in additional seeds from the surrounding forest (Chazdon *et al*., 2017). Whereas the lack of perches in recent gaps or abandoned lands may limit seed rain of animal-dispersed seeds in some areas, nurse plants in arid and semi-arid ecosystems are often the only perches available and thus provide both high seed input in a non-random pattern and a favourable microclimate for bird-dispersed species.

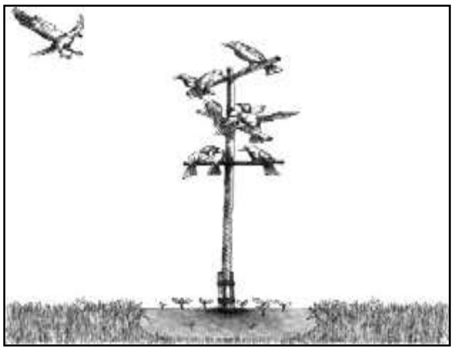



Figure 18. Bird perches can help attract seed dispersing birds to ANR site
Source: FAO, 2019 (left) & Chazdon *et al*., 2017 (right)

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.

Advantages of seed dispersal

Seed dispersal agents can be advantageous:

1. In escape from density-or distance-dependent seed and seedling mortality,
2. By colonization of suitable sites unpredictable in space and time, and
3. By directed dispersal to particular sites with a relatively high probability of survival rate.

5.9. Developing sustainable community 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. Experience in ANR implementation in Southeast Asia and in forest sector development projects of Ethiopia have 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 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.

Trailing and capacity building is also essential. The concept and what encompasses ANR should be clearly known by all stakeholders. Therefore, a series of ANR training events should be conducted, which envisioned empowering a cadre of ANR practitioners from the communities, non-government units, the academy, research institutions, civil society organizations and other stakeholders all over the country. Stakeholders should be 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 programs.

ANR should also generate short term and long term incentives. These incentives could be material such as employment, seedling provision; buying seedlings from community, social recognition are essential issues to consider during ANR program facilitation. It is also essential to avoid perverse incentives that could arise due to ANR. Such as loss of communal land that used to be pasture lands or other multipurpose and loss of such land without their consent is disastrous and hence should be avoided.

Chapter 6: Monitoring

Monitoring is an essential component of any forest restoration project and ANR. Monitoring enables adaptive management based on feedback data and informs the effectiveness and impact of restoration activities implemented. The ultimate goal of restoration monitoring is to provide the information necessary to answer specific management objectives. Monitoring should base on a robust monitoring program, an efficient data-storage and retrieval system, and synthesis of the monitoring information to provide the scientific knowledge needed for informed management decisions.

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.) and setting a reference ecosystem serves as a model for planning a restoration project, and later for its evaluation. In its simplest form, the reference is an actual site, its written description, or both (Figure 20).

At beginning of intervention-2016

After intervention-2019

Figure 20: **Reference setting**

Source: IS-FSDP, 2016 and 2019

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.

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 expert’s 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) (Broad head *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.

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