Assisted natural regeneration: harnessing nature for restoration

K. Shono, R. Chazdon, B. Bodin, S. Wilson and P. Durst

Giving natural processes a boost can be a cost-effective means for restoring forests and drylands at scale in diverse contexts.

Kenichi Shono is Forestry Officer at FAO, Rome.
Robin Chazdon is Research Professor at the University of the Sunshine Coast, Sippy Downs, Australia.
Blaise Bodin is a consultant in the Forest and Landscape Restoration Mechanism, FAO, Rome, Italy.
Sarah Jane Wilson is a postdoctoral researcher at the School of Environmental Studies, University of Victoria, Victoria, Canada.
Patrick Durst is an independent forestry and natural resources management consultant and formerly Senior Forestry Officer at FAO, Bangkok, Thailand.

Above: A naturally regenerated forest landscape in Bohol, the Philippines

Countries worldwide have committed to restoring millions of hectares (ha) of degraded land in the next decade. A myriad of national and local governments, non-profit organizations, actors from the private sector and local communities are ramping up efforts to plan, execute and monitor large-scale restoration. Given the scale of the challenge, it is essential that scarce resources are allocated efficiently. Certain sites where forest and shrubland restoration is desired will require active tree-planting strategies, with significant cost and infrastructure demands in terms of site preparation and seed and seedling supply-chain development.

Complementary, lower-cost options are needed if ecosystem restoration is to be achieved at the necessary scale. Natural regeneration is gaining recognition as a practical approach that allows the cost-efficient restoration of forests and drylands at a large scale. It is a biological process, and it can be assisted (hence "assisted natural regeneration", or ANR) by first understanding the obstacles to it and then overcoming them (FAO, 2019).

Over the past century, forests have been naturally regenerating in Europe and the United States of America at very large scales following the abandonment of agricultural lands (in some cases with active assistance), a trend that is now becoming evident around the world (Chazdon *et al*., 2020). In the tropics, where net forest loss is still occurring, large-scale natural regeneration following agricultural abandonment tends to be a more recent phenomenon (Song *et al*., 2018). In the tropical Andes, 500 000 ha of woody vegetation is estimated to have regrown over the period 2001–2014 (Aide *et al*., 2019). In Brazil, 2.7 million ha of the Atlantic forest regenerated naturally between 1996 and 2015 (Crouzeilles *et al*., 2020), a phenomenon attributed to agricultural intensification on the most suitable

agricultural lands and the abandonment of others (Chazdon *et al*., 2020).

ANR is a simple, relatively low-cost restoration method that can enhance the productivity and ecosystem functions of deforested or degraded lands. The method aims to accelerate, rather than replace, natural successional processes by removing or reducing barriers to natural regeneration such as soil degradation, competition with weedy species, and recurring disturbances such as fire, grazing and wood harvesting (Shono, Cadaweng and Durst, 2007). Properly applied, ANR can speed the recovery of native ecosystems and at least some of their original functions (Chazdon, 2017). It comprises one element of overall efforts to promote the recovery of ecological integrity.[1]

ANR encompasses a range of restoration interventions that can help achieve restoration goals and related policy objectives. It can also be used as a component of larger-scale forest and landscape restoration (IUCN and World Resources Institute, 2014) and in national action plans to support ecosystem restoration targets such as Aichi Biodiversity Target 15 (Chazdon and Guariguata, 2016), land degradation neutrality targets (Kust, Andreeva and Cowie, 2017) and commitments under the Bonn Challenge.

ANR is a relatively recent but growing field of restoration science, with examples of successful applications around the world multiplying in recent years (FAO, 2019; Chazdon *et al*., 2020). This article describes the many advantages of ANR as a restoration intervention and its limitations, and it stresses the importance of tailoring interventions to the local socio-environmental context. It explores the method's advantages and limitations in four case studies (in Australia, Burkina Faso, the Philippines and Indonesia) in different restoration contexts. Finally, it proposes a typology of ANR interventions and a decision-making process for deciding which approach is most relevant, alongside other types of restoration interventions, depending on the context and restoration objectives.

PRINCIPLES, ADVANTAGES AND LIMITATIONS

The approach for restoring a degraded area should be determined based on the objectives of restoration, the area's ecological and environmental conditions and socio-economic and cultural context, and the availability of funds. If, for example, the objectives prioritize quick results and predictable returns on investment through the output of fibre or timber, it may be most appropriate to invest in intensive tree plantations. But if there is a need to both restore ecological functioning (e.g. in terms of biodiversity, water and soils) and produce diverse end products, ANR may be an appropriate and cost-effective approach.

When practised effectively, ANR can accelerate the process of natural

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Forest restored through ANR

[1] Ecological integrity refers to the state or condition of an ecosystem that displays the biodiversity characteristics of the reference, such as species composition and community structure, and is fully capable of sustaining normal ecosystem functioning (McDonald *et al*., 2016; SER, 2004).

regeneration in deforested and otherwise degraded forest ecosystems and enhance native species diversity and conservation (Chazdon, 2013). In human-modified landscapes, ANR can be an important natural solution for mitigating and adapting to climate change and increasing the supply of other ecosystem services (Wilson *et al*., 2017) while also generating economic benefits for local farmers at multiple scales (Reij and Garrity, 2016; Smale, Tappan and Reij, 2018). ANR can protect and rehabilitate watersheds (Dugan *et al*., 2003; Paudyal *et al*., 2017; Yang *et al*., 2018) and increase carbon storage (Evans *et al*., 2015). Because of spatial variability in the ecological and social factors that influence natural regeneration outcomes, ANR is a highly flexible and adaptive approach to restoration that is context- and site-specific (FAO, 2019). The inherent flexibility of ANR places interventions on a spectrum between full tree-planting approaches and passive (spontaneous) natural regeneration processes.

In areas where grazing is a driver of land degradation, exclosures (i.e. areas in which large grazing animals are excluded by fencing) have proved effective for restoring ecosystems while providing economic benefits for local communities. There are many successful examples of this approach in the Sahel: in Burkina Faso, for example, small exclosures established as part of small-scale landscape restoration strategies have reduced food shortages by enabling smallholders to harvest diverse foods and non-edible forest products (including fodder for livestock, small wildlife, and crops of cereals and legumes) in and around the exclosures (Djenontin, Djoudi and Zida, 2015). In the Amhara region of northern Ethiopia, exclosures installed on communal grazing lands increased above-ground biomass, plant species diversity and fodder production and reduced soil erosion within seven years (Mekuria *et al*., 2015). In some cases, physical fencing may not be required if local people adhere to "social fencing" (in which community members agree among themselves to police their grazing regimes) as a way of reducing land-use pressure on degraded areas long enough to enable regeneration. Social fencing can succeed where there is strong community cohesion and a shared vision, and where access is rigorously restricted. China has a long history of "mountain closure", which employs social fencing to provide forests with sufficient time to regenerate naturally (Chokkalingam *et al*., 2018).

ANR can also be used as part of silvopastoral and agroforestry systems, as demonstrated in the wide adoption of farmer-managed natural regeneration (FMNR) in Africa. FMNR is a social-forestry approach in which farmers play a central role in promoting and managing natural regeneration. It can provide many benefits for farmers, including increasing crop and pastoral production, income from the managed harvesting of woodfuel and fodder, and the diversity of native trees in the landscape (Birch *et al*., 2016). As farmers in the Colombian Andes transitioned from pasture monocultures to silvopastoral systems, the exclusion of cattle by fencing led to the recovery of the structure and diversity of riparian forests within ten years (Calle and Holl, 2019).

In many regions, Indigenous Peoples and local communities have excellent knowledge of local successional and recovery processes. This knowledge can help in achieving successful ANR, thereby enhancing ecosystem recovery and capitalizing on local knowledge and cultures (Reyes-Garcia *et al*., 2019). For example, traditional shifting-cultivators have a vast knowledge of species characteristics in swidden fallows and can help identify native tree species with potential to promote natural regeneration and the recovery of biodiversity (Wangpakapattanawong *et al*., 2010; Douterlungne *et al*., 2010). Thus, ANR promotes cultural values, uses local knowledge, and helps keep traditional practices alive.

A key advantage of ANR is the low requirement for infrastructure and capital investment and the significantly lower costs of implementation and maintenance compared with full tree-planting. These qualities contribute to the effectiveness of ANR for household-, farm-, and community-based restoration activities that do not have access to or a need for external financing. In many areas, including parts of the Philippines, ANR is being implemented widely by local communities working in small watersheds. The average overall cost of site protection and weed control is in the range of USD 20 to USD 579 per ha for establishment, and it remains low for annual maintenance (Table 1). Enrichment

Table 1. Costs of establishing and maintaining assisted natural regeneration in the tropics based on data from the Americas, Africa and Asia

Cost category	Direct cost
Establishment cost per ha, year 1	Average = USD 257; range = USD 20–579
Annual maintenance and monitoring cost per ha per year, years 1–5	Average unavailable; range = USD 31–213
Annual maintenance and monitoring cost per ha per year, years 5–15	Average unavailable; range = USD 14–17

Note: The costs shown are averages for restoring tropical forest landscapes using ANR, including labour, inputs and equipment derived from a systematic review of literature and available field data comprising case studies, expert opinion, cost modelling and experimental trials in Australia, Brazil, Malaysia, the Niger, the Philippines and South Africa. Estimates are based on quantified total costs for establishing and maintaining ANR, including weeding and protection against fire, grazing and the unsustainable collection of woodfuel and other forest products.
Sources: Dugan (2011); Evans *et al*. (2015); Molin *et al*. (2018); Mugwedi *et al*. (2018); Ong (2011); Pavanelli and Voulvoulis (2019); Reij and Garrity (2016).

planting and fencing add to the cost but can also increase the financial and livelihood benefits (Maier *et al*., 2018). Enrichment planting is recommended in cases where natural regeneration is insufficient or the desired tree species are absent (FAO, 2019). The cost increases with additional interventions to attract seed dispersal.

Because of its lower cost and infrastructure requirements, ANR can be an appropriate approach for large-scale forest restoration, particularly following major disturbances such as fires and floods or on abandoned agricultural lands (Chazdon and Guariguata, 2016). Site-preparation measures alone, such as harrowing and initial herbicide application, have been shown to effectively stimulate natural tree regeneration in intensively used pastures in the southern Amazon, with no tree-planting required (Rezende and Vieira, 2019). In Brazil's Atlantic Forest region, it is estimated that 18.8 million ha could be restored using ANR, reducing implementation costs by USD 90.6 billion compared with the cost of full tree-planting (Crouzeilles *et al*., 2020). Estimation of the full spatial potential of ANR in other regions and countries is limited by a lack of assessments and maps of local site potential for natural regeneration.

ANR interventions can ameliorate site-specific obstacles to natural regeneration and support the livelihoods of local people. Interventions to suppress weeds and release the natural regeneration of desired species appear to be more effective at accelerating forest regeneration when used in combination (Shoo and Catterall, 2013). For example, restricting grazing alone may be insufficient because non-native species may proliferate and inhibit the establishment of native species. On the Pacific coast of Mexico, the recovery of tropical dry forest on former pasture was significantly accelerated by the removal of climbers and by soil ploughing (Méndez-Toribio *et al*., 2019). Where natural regeneration is limited by seed dispersal, the placement of artificial perches for seed-dispersing animals can enhance seed arrival and seedling establishment (Guidetti *et al*., 2016).

Several aspects of ANR limit its applicability in forest restoration efforts. Compared with conventional reforestation, tree growth and stand development are slower and commercial yields of timber and fibre are lower and less uniform than in intensively managed forest plantations. ANR is labour-intensive in its early stages, particularly where naturally regenerating trees face heavy competition from weeds and grasses, which therefore must be managed. ANR displaces grazing and woodfuel collection, so these needs must be satisfied elsewhere. Finally, ANR is poorly understood and rarely advocated by policymakers, who may be more familiar with active tree-planting approaches to the restoration of degraded sites.

Below, four case studies illustrate some of the points made above and demonstrate the advantages and limitations of ANR.

Case study 1. Assisted natural regeneration with fencing restores native woodlands and livelihoods

Context. Climate change and unsustainable agricultural and grazing practices have reduced tree cover in the Sahel, leading to desertification and a lack of woodland and water resources to support the lives of local people. The Switzerland-based non-governmental organization (NGO) newTree introduced ANR with fencing to central and northern areas of Burkina Faso in 2003 and, over a ten-year period, assessed the impact of this on income generation and vegetation regeneration.[2]

Interventions. Contracts were arranged between newTree and farmers. Farmers contributed labour to construct fences and newTree provided fence materials and technical support. Each fenced site was surrounded by a cultivated buffer area of agroforests. Vegetation in each fenced site was inventoried every five years. One hundred and ninety-eight sites were fenced between 2003 and 2012, and families and farmer groups protected 560 ha of fenced land.

[2] The information in this case study is based on Belem *et al*. (2017).

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Fodder production in fenced and agroforestry buffer areas as part of ANR helped increase income for local farmers in Burkina Faso

Outcomes. After eight years, tree abundance had increased five- to six-fold in fenced areas compared with areas outside the fences and species diversity had doubled. Trees grew faster and produced more fruit inside the fences. ANR contributed 21–23 percent of farmers' gross profit through the collection of non-wood forest products such as honey, fodder and seed oil. Tree regrowth enhanced biodiversity and reduced vulnerability to climate change. Farmers were actively engaged in the restoration process and protected the fenced areas from illegal wood cutting.

Forest restored through FMNR implemented by local farmers in Timor-Leste

Case study 2. Farmer-managed natural regeneration in Timor-Leste

Context. Overgrazing and annual burning in the Aileu region of Timor-Leste led to declining soil fertility, decreased water-storage capacity, increased erosion and landslides. World Vision's Building Resilience to a Changing Climate and Environment project, implemented from 2011 to 2016, implemented FMNR to address these issues. Before the project, slash-and-burn agriculture was common in Aileu, but a growing population combined with reduced forest area made this practice unsustainable.[3]

Implementation. FMNR was implemented as a holistic land management strategy to improve farming and sustain livelihoods. Key implementation features were demonstration plots, community training, and the supplementation of natural regeneration with tree-planting to achieve specific outcomes (e.g. fruit, fodder and timber production). The strategy for promoting FMNR involved identifying the main environmental problems faced by communities and how changes in practice could solve them.

Outcomes. More than 50 ha of forests was restored in demonstration plots, with greater improvement achieved on private land. Forest cover, biodiversity and soil fertility had all increased after one year and soil erosion had declined. A decrease in vegetation burning and the adoption of slash-and-mulch practices created darker, richer soils and enabled trees of various native species to regenerate. After five years, FMNR had led to the better management of natural resources, increased forest cover and improved methods of conflict resolution. The rate of uptake by farmers was very high. More than 90 percent of farmers who were aware of the new land management technique adopted elements of FMNR, and they continued to implement these practices after the project ended. Farmers also reported increases in income because of higher vegetable, fruit and livestock production, and women reported an increase in shared decision-making. Across 51 ha in 46 community demonstration plots and an additional 50 ha of private land, 12 000 people benefited from the positive impacts of FMNR.

Case study 3. Restoring the Danao watershed through assisted natural regeneration

Context. Increasing population pressure rendered traditional slash-and-burn agriculture unsustainable in the Danao watershed in Bohol, the Philippines, leading to deforestation and land degradation. The fire-prone grass *Imperata cylindrica* became dominant and inhibited natural forest recovery in the area. In 2006, FAO, the Department of Environment and Natural Resources of the Philippines, the Bagong Pagasa Foundation, local organizers and local governments initiated an ANR project in the Danao municipality with the aim of restoring a degraded and deforested watershed area and thereby demonstrating the potential of ANR as a forest restoration strategy. Initially, stakeholders were unaccustomed to using ANR, and government authorities at multiple levels were reluctant to change from conventional tree-planting. Considerable effort was required to encourage local stakeholders to participate, secure the support of local NGOs and educational institutions, and build local capacity.[4]

[3] The information in this case study was obtained from FMNR (undated); Rinaudo (2014); World Vision Timor Leste (2016); T. Rinaudo, personal communication, December 2019; G. Goncalves de Oliveira, personal communication, July 2020.

[4] The information in this case study is based on Castillo (2018); de la Torre (2009); Dugan *et al.* (in press); FAO (2011); FAO (2019).

Implementation. ANR was implemented on a 25-ha demonstration plot. Interventions included establishing firebreaks, employing community members to conduct fire patrols, staking and protecting naturally regenerated seedlings and saplings, reducing competition from grasses by weeding and pressing,[5] and controlling grazing and woodfuel-gathering. Farmers planted food crops in firebreaks to provide economic benefits during restoration. Over a three-year period, the implementation of ANR cost USD 579 per ha, compared with USD 1 048 per ha for a more conventional approach involving tree-planting.

Outcomes. Observable changes in biodiversity were evident within 18 months, most notably in grassland areas. Several tree species naturally regenerated in these areas, enhancing natural forest recovery. Community members obtained socio-economic benefits. Cash crops planted in firebreaks (e.g. cassava, bananas, pineapples and peanuts) generated income, and local people were paid to patrol and protect the areas against illegal harvesting, grazing, and fire. ANR activities also improved prospects for expanding ecotourism. The Danao site became a showcase for ANR success and feasibility around the world. Based on its success, an increasing number of government agencies, NGOs and donors in the region now recognize and recommend the implementation of ANR.

5 Pressing is a technique whereby grasses are pressed down by stepping on wooden boards with a rope tied to each end of the board draped over the shoulders of the user.

Case study 4. Assisted natural regeneration stimulates native tree recruitment in a subtropical rainforest ecosystem

Context. Uebel, Wilson and Shoo (2017) report on a research project conducted from 2005 to 2015 to determine effective low-cost approaches to enhancing natural regeneration. The study was conducted in the Numinbah Conservation Area in southeast Queensland, Australia. This area was settled in the 1870s and used for timber harvesting, dairy and beef production, and banana plantations. Invasive shrubs are abundant and suppress the recruitment of native vegetation in the area.

Interventions. Baseline conditions were measured at all sites. Grazing was halted at some sites for ten years, with some of those also subject to 4–6 years of herbicide control of non-native plant species to encourage the regeneration of native species. Vegetation surveys were conducted for more than ten years to quantify canopy cover and the recruitment of native tree and shrub species.

Outcomes. The control of non-native plant species facilitated successful native tree and shrub recruitment, increased species richness and significantly accelerated forest recovery relative to grazed and ungrazed-only sites. Nevertheless, restricting grazing alone was insufficient to stimulate the regeneration of native species.

WHEN TO APPLY ASSISTED NATURAL REGENERATION

The key to unlocking the full potential of natural regeneration in forest and dryland restoration lies in identifying those areas where ANR is likely to succeed, from both social (encompassing policy, economics, demographics, tenure and regulations) and ecological perspectives (Crouzeilles *et al*., 2019). These considerations include ensuring:

- an adequate density of existing natural regeneration of tree seedlings;
- the availability of seed inputs from nearby remnant forest patches or the soil seed bank;
- the ability to prevent or at least minimize human-induced disturbances, such as fire, grazing and the unsustainable harvesting of forest products;
- the presence of social support, with incentives and long-term benefits for the participation of local communities in forest restoration activities;
- a shared vision among local stakeholders of the objectives of restoration and clear land and resource tenure;
- the ability to negotiate outcomes across sectors operating in the area;
- a favourable policy and regulatory

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A family presses down* Imperata cylindrica *grass around regenerating trees, a technique to prevent and reduce competition and the severity of fires

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*A site at which ANR was implemented to restore degraded subtropical rainforest in the Numinbah Conservation Area, Queensland, Australia. The cleared site had been in pasture for at least 30 years. Grazing was excluded in 2005 and assisted regeneration was initiated in 2010. Before treatment, the site was dominated by non-native species, predominantly lantana (*Lantana camara*) thickets and wild tobacco (*Solanum mauritianum*)*

environment for restoration, and political will; and
- capacity, technical knowledge and support among local governments and civil-society organizations.

Modalities of assisted natural regeneration

ANR is a flexible and adaptable approach that can be applied in a variety of socio-economic and ecological contexts. Some of these are described below.

To accelerate and enrich forest regeneration on heavily degraded shrub/grasslands. This approach typically includes grass pressing, the liberation of desired tree seedlings, working with local communities to control external disturbances, and enrichment planting with tree species of economic, social or environmental value, depending on the specific restoration objectives (FAO, 2019; Wangpakapattanawong *et al*., 2010; Shono, Cadaweng and Durst, 2007). This approach can be applied to transform abandoned agricultural lands into regenerating forests that provide landowners and local communities with multiple benefits (Chazdon *et al*., 2020).

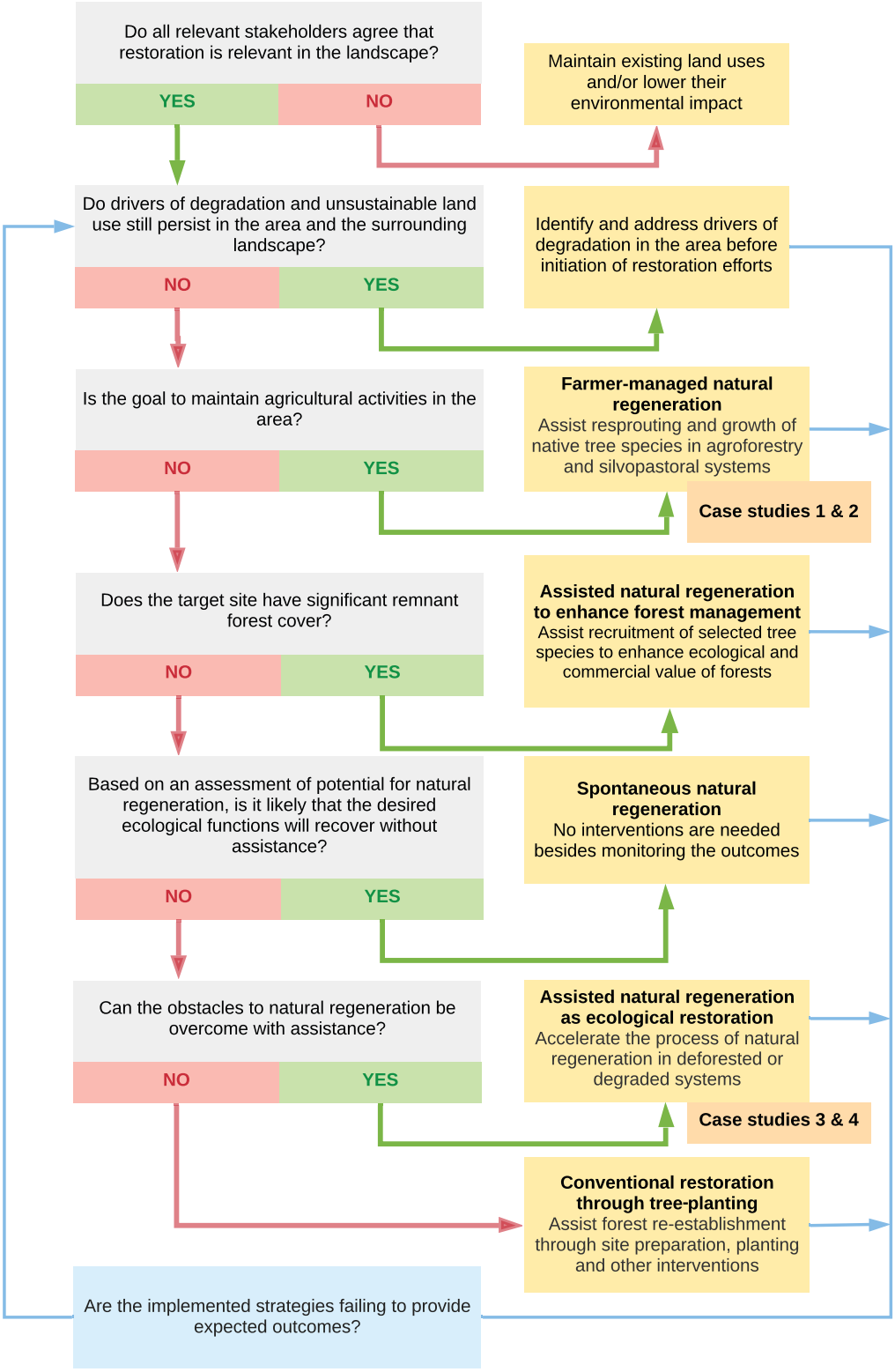
As a component of forest management. ANR can be part of forest management practices aimed at improving the environmental and commercial value of forest stands through thinning, the control of invasive species, enrichment planting, and the prevention of fires and other disturbances. This approach was used successfully to increase the growth of valuable timber species in degraded shrubby forests in Cambodia, where fire prevention, combined with the removal of competing vegetation such as vines and climbing bamboo, resulted in significant stand improvement (Chokkalingam *et al*., 2018). In the Philippines, a similar approach has been applied to remnant gallery forests to improve them and to gradually expand them into adjacent deforested areas. In China, the application of ANR in secondary forests resulted in significant increases in the supply of ecosystem services (Yang *et al*., 2018).

As a component of agriculture. ANR can be used to increase agricultural yields and as a component of agro-silvopastoral systems based on naturally regenerating trees and shrubs – also referred to as FMNR. Examples of successful FMNR in Africa (such as in case study 1) provide evidence of the increased production of staple crops, particularly in drought years, the alleviation of woodfuel shortages, and higher survival rates of livestock in dry years. Indigenous trees and shrubs that have regenerated provide habitat and food for wildlife, as well as greater access to wild foods and medicinal plants for local communities (United Nations, undated; Smale, Tappan and Reij, 2018; Reij and Garrity, 2016). In 2018, 34 years after FMNR was first introduced to the Miradi region of the Niger, it has been adopted on an estimated 7 million ha (Smale, Tappan and Reij, 2018). In Sumatra, Indonesia, ANR was applied on heavily degraded hillsides to establish agroforests, which provided communities with income from the sale of agroforestry products and carbon credits (Burgers and Farida, 2017).

Figure 1 illustrates a decision-making process that can be used to determine whether natural regeneration can be a viable restoration option for a given situation and, if so, whether it would need to be assisted and which modality of ANR would be applicable.

CONCLUSION

All successful forest restoration and forest management initiatives begin by developing a shared vision among key stakeholders and local people of the objectives of restoration and land-use management. If that vision includes a strong desire and appreciation for increasing the ecological functioning of forests and generating diverse socio-economic benefits, there will often be excellent prospects for integrating ANR into the management regime. ANR is particularly promising because of its relatively low cost, with ANR approaches



1 Decision tree to help determine when to use natural regeneration or assisted natural regeneration versus conventional restoration

typically requiring less than half the investment required for conventional reforestation.

ANR should be seen as one approach among many available to support forest and dryland restoration and management. Experience has demonstrated that ANR practices fit well with current principles underpinning landscape approaches to resource management. Various elements of ANR can be applied in different areas of typical landscape mosaics, such as to increase the regeneration of preferred species in degraded forests, improve agricultural yields through FMNR, and restore highly degraded sites at a relatively low cost.

Experiences in ANR around the world indicate that many of the requisites for successful ANR are identical to those needed for successful conventional reforestation and tree-planting, such as clear land tenure, supportive policies, benefits accruing to local stakeholders, and sound technical expertise. ANR may provide added benefits compared with conventional reforestation, however, by facilitating the development of more-species-diverse ecosystems (and consequently more diverse product lines) and regenerating sites with native species that are inherently well-adapted to local conditions at a considerably lower cost.

Efforts to scale up ANR globally to capture these advantages may require changes in mindsets, policies and practices (Chazdon *et al*. 2020). Greater awareness is needed among policymakers, extension workers, resource managers and the public of the potential of ANR – and that forests can be regenerated naturally without resorting to the planting of trees. In many instances, new policies will be needed to provide enabling conditions for the widespread application of ANR under various socio-economic (including cultural) and environmental conditions. To succeed, ANR also needs effective monitoring, and stakeholders need incentives to apply it that match those provided to catalyse conventional reforestation. Finally, given the necessity of engaging local stakeholders and winning their support for successful forest and dryland restoration and management, there is a critical need for creative field facilitators who are capable of working with multiple sectors and diverse political elements to motivate and support effective ANR across the full range of landscapes and contexts.

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