Food and Agriculture
Organization of the
United Nations

Agroforestry for landscape restoration

Exploring the potential of agroforestry to enhance the sustainability and resilience of degraded landscapes

FLRM – Forest and Landscape Restoration Mechanism

Restoring landscapes for enhanced livelihoods

Photo cover: Agroforestry landscape, Uganda. ©beccacantpark

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Exploring the potential of agroforestry to enhance the sustainability and resilience of degraded landscapes

By:

Anique **Hillbrand**, FAO

Simone **Borelli**, FAO

Michela **Conigliaro**, FAO

Alain **Olivier**, Visiting Professor, FAO

Food and Agriculture Organization of the United Nations

Rome, 2017

Required citation:

FAO. 2017. Agroforestry for landscape restoration:
Exploring the potential of agroforestry to enhance the sustainability and resilienceof degradedlandscapes.
Rome. https://doi.org/10.4060/i7374e

Contents

Key messages

- Agroforestry can provide many ecosystem services. It is a suitable tool for landscape restoration because it can enhance physical, chemical and biological soil characteristics, thereby increasing soil fertility, controlling erosion and improving water availability.
- Agroforestry systems that provide permanent tree cover can be valuable forest and landscape restoration options, especially in initiatives in which neither natural forest restoration nor full sun crops are viable.
- Agroforestry can enhance livelihoods in rural communities by providing a variety of food, fodder and tree products, which increase food and nutrition security, generate income and alleviate poverty.
- The restoration of degraded landscapes using agroforestry can increase the resilience of communities to shocks, including drought and food shortages, and help mitigate climate change.
- The widespread uptake of agroforestry requires an enabling legal and policy environment that guarantees rights to – and ownership of – trees and land, provides farmers with incentives, promotes investment, and facilitates the marketing of agroforestry products.

Agroforestry is the collective term for land-use systems and technologies in which woody perennials (trees, shrubs, palms and bamboos, etc.) are used deliberately on the same land-management units as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between the different components.[1]

Forest and landscape restoration is “an active process that brings people together to identify, negotiate and implement practices that restore an agreed optimal balance of the ecological, social and economic benefits of forests and trees within a broader pattern of land uses”.[2]

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The global context: land degradation

1

Although there is no single internationally agreed definition of land degradation, for the purposes of this paper we define degraded land as land that has lost some degree of its natural productivity due to human-caused processes.[3] Most recent definitions of land degradation also embrace negative changes in the capacity of ecosystems to provide a variety of social and environmental goods and services. Causes of degradation include inappropriate land use and management, such as the overexploitation of local vegetation, overgrazing, and excessive tillage and crop-residue removal. Types of degradation include soil fertility decline, nutrient imbalance, erosion, compaction, acidification and salinization. Such phenomena can lead to excessive water runoff, low soil moisture, and a reduced capacity of soils to regulate water flows. At the landscape scale, land degradation can also lead to a loss of biodiversity and cause negative microclimatic changes, thus facilitating desertification. Degradation can exacerbate climate change by increasing greenhouse gas emissions.

Land degradation can have serious consequences for the livelihoods of rural people by decreasing the supply of good-quality water and reducing food and nutrition security. Over time, land degradation can increase the vulnerability of rural communities to biological and environmental hazards and to the effects of climate change.

It is estimated that 25 percent of the world's lands are either highly degraded or subject to high rates of degradation.[4] In Africa, FAO estimates that 65 percent of arable land, 30 percent of grazing land and 20 percent of forests are degraded.[5] Land degradation is still occurring at a rapid pace, with some 12 million hectares of land degraded globally each year. As a result, the productivity of the world's lands continues to decline – even as the human population and demand for food and goods grow. It has been estimated that, worldwide, land degradation costs between USD 6.3 trillion and USD 10.6 trillion annually. The rural poor are among the most affected.[6]

How can the world feed more than 9.7 billion people in 2050,[7] if over one-fifth of global croplands and nearly one-third of remaining forests are degraded? How can food insecurity and poverty be eradicated if key resources are becoming scarcer?

A crucial part of the answer to these questions is to halt and reverse land degradation. The restoration of degraded lands, therefore, can be a valuable tool for enhancing livelihoods in rural communities and increasing the sustainability of rural development. The area of land potentially available for landscape restoration has been estimated at 2.2 billion hectares.[8] Of this, 1.5 billion hectares are best suited to mosaic restoration, in which forests and trees are combined with other land uses, such as agroforestry. A further 1 billion hectares of croplands and densely populated rural areas on former forestlands would benefit from the establishment of trees in strategic places to protect and enhance agricultural productivity and other ecosystem functions.[9]

The international community has responded to concerns about land degradation with the Bonn Challenge, a global effort launched in 2011 that aims to restore 150 million hectares of deforested and degraded land by 2020. The New York Declaration on Forests, agreed in 2014, raised this target to 350 million hectares by 2030.[10] Landscape restoration also contributes to the achievement of the Sustainable Development Goals (SDGs), especially SDG15, which is to protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss, as well as SDG1 (no poverty), SDG2 (zero hunger), SDG6 (clean water and sanitation) and SDG13 (climate action). Restoration is mentioned in the Paris Agreement on climate change as a valuable tool for addressing climate change and in the Convention on Biological Diversity (CBD) as a means for reducing biodiversity loss. In 2016, the United Nations Convention to Combat Desertification (UNCCD) established the Land Degradation Neutrality Fund, the aim of which is to enable the private sector to support policies and make investments for a land-degradation-neutral world by 2030.

Agroforestry is one of a wide range of approaches for restoring degraded forests and agricultural lands, thereby contributing to landscape restoration. This brief examines the potential of agroforestry systems to restore land productivity, conserve biodiversity, increase the resilience of agro-ecosystems, alleviate poverty and contribute to food security and nutrition.

An example of a well-managed silvopastoral system in the Reserva Natural El Hatico near Palmira, Colombia. ©Neil Palmer (CIAT)

Agroforestry for landscape restoration

2

According to remote sensing data, 43 percent of all agricultural land had at least 10 percent tree cover in 2009, representing over 1 billion hectares of land.[11] This gives an indication of the large extent of agroforestry, which is practised by more than 1.2 billion people.[12] For example, cocoa agroforestry systems (in which cocoa grows in the shade of tree canopies) cover 7.8 million hectares worldwide; silvopastoral systems (in which trees are combined with livestock) cover 9.2 million hectares in Central America alone; and jungle rubber forests (a form of agroforestry) account for 2.1 million hectares in Indonesia.[13] Agroforestry can diversify and increase agricultural production while also providing land users with other economic, social and environmental benefits.

Several agroforestry approaches are available for restoring and increasing land productivity while also meeting the needs of low-income farmers, and the presence of trees confers a number of advantages. For example, trees can fix nitrogen, stabilize the soil, and be used in terracing, contour cultivation and strip-cropping to combat soil erosion and increase soil fertility.[14] Planted in windbreaks and shelterbelts, trees can protect soils against wind erosion. Trees can also be planted in improved fallows and alley-cropping systems, with the branches pruned and applied as mulch to increase soil organic matter and nutrient status. In silvopastoral systems, tree canopies provide livestock with shade and wind protection and thus indirectly improve animal welfare, health and productivity.[15]

As described below, agroforestry systems can increase soil productivity, control erosion and regulate water availability in degraded or less-productive lands. Agroforestry can also provide local communities with a wide range of food and non-food products, thereby contributing to food and nutrition security, generating income, improving livelihoods, and combating poverty.

Agroforestry for ecosystem services

Agroforestry systems can provide a wide range of ecosystem services, including supporting services (e.g. pollination and carbon cycling); regulating services (e.g. protection against wind, increased water quality, biological pest control and nitrogen fixation); and provisioning services (e.g. food and non-food products for home consumption and income generation). If properly designed and managed, agroforestry systems can help restore ecosystems, thus contributing to biodiversity conservation and climate-change adaptation and mitigation.[16] Three of the most important ecosystem services provided by agroforestry – improved soil productivity, enhanced erosion control and increased water availability – are addressed in more detail below.

A mixed tree, crop and livestock agroforestry system in Dickson's village, Kenya. ©TreesForTheFuture

Agroforestry for restored soil productivity

Significant declines in soil fertility have been observed worldwide as a consequence of land degradation and overexploitation, reducing the productivity of the land and increasing food insecurity among local communities. Soil fertility declines when the quantity of nutrients removed from the soil in harvested products exceeds that being added to the arable soil.[17] Declines can also occur due to erosion and inappropriate farming practices such as the use of monocultures and frequent tillage, the removal of plant residues, and a lack of adequate fallow periods.

The recovery of soil fertility can be a long process when soil organic matter has been depleted and soil structure damaged. Tree characteristics that help increase soil fertility include high biomass production, nitrogen fixation, mycorrhizal associations, dense, deep networks of fine roots, and a capacity to grow in poor soils. Trees can help rebuild soil organic matter by retrieving nutrients from deeper soil horizons and weathering rock and adding them to the surface layers of the soil through leaf litter.[18] Many tree species can also prevent nutrient leaching because of their deep root systems, and trees can be used to combat soil salinization and acidification. The use of nitrogen-fixing trees can increase soil fertility by adding nitrogen to the agro-ecosystem, with the higher soil nitrogen content[19] potentially increasing the productivity of agricultural crops. Experiments in Zambia, for example, showed that maize yields increased by 88–190 percent when grown in an agroforestry system under the canopies of *Faidherbia albida* trees.

Many studies have demonstrated that soils under trees in agroforestry systems have higher levels of organic carbon, mineralizable nitrogen, phosphorous, potassium and calcium compared with soils beyond the influence of trees. Agroforestry can also have a positive impact on soil microbial biomass and the diversity of soil microfauna (e.g. earthworms).[20]

In general, well-managed agroforestry systems have positive effects on soil fertility compared with monocultures because of the contributions of trees (Box 1). Tree plantation–crop combinations, in which (for example) tea, coffee or cocoa are cultivated under trees, and homegardens, in which a high diversity of tree and crop species is grown on the same piece of land, are examples of agroforestry systems that exhibit higher soil fertility than monocultures of the same crops. In the Sahel, for example, agroforestry parklands with tree species such as *Parkia biglobosa* and *Vitellaria paradoxa* have been proven to be more fertile than fields without trees.[21] The same observation has been made for silvopastoral systems that combine trees and livestock compared with livestock alone.[22]

BOX 1

Restoration of soil fertility through agroforestry in the humid highlands of Cameroon

As part of a project designed to help farmers in the highlands of Cameroon increase the fertility of their soils through agroforestry, training sessions were offered to local non-governmental organizations and farmer group leaders to enhance their knowledge of indigenous techniques for improving soil fertility. The project also made available seeds of leguminous tree species to 160 farmer groups, who established demonstration plots and seed banks and planted leguminous tree seedlings on their lands. Nitrogen lost in previous decades was replenished using agroforestry techniques such as hedgerow intercropping with *Acacia angustissima*; biomass transfer from tithonia (*Tithonia diversifolia*); improved manure using calliandra (*Calliandra calothyrsus*) biomass; and improved fallows using nitrogen-fixing shrubs such as sesbania (*Sesbania* spp.), tephrosia (*Tephrosia* spp.), pigeon pea (*Cajanus cajan*) and gliricidia (*Gliricidia sepium*).

Project results show that soils are better-retained using tree hedges than in untreated terraces, and contour hedges have reduced runoff by about 70 percent. Farmers testify that crop performance on previously degraded land is greatly improved. Maize yields have almost doubled in plots in which agroforestry interventions have been implemented. Moreover, tree hedges are providing high-quality fodder for livestock, stakes for climbing beans, and woodfuel.

Source : Atia Iseli, J., ed. 2010. *Restoration of soil fertility through agroforestry technologies and innovations*. Food for Progress Info No. 005, June. World Agroforestry Centre.

Agroforestry for reduced soil erosion

Soil erosion occurs when the top layer of the soil is washed or blown away, and it can be caused by both natural and anthropogenic factors. Although it has occurred for millennia as part of geological processes, the severity of soil erosion has increased in recent decades, due mainly to the overexploitation of soils by people.

Practices leading to soil erosion include forest clearing; cropping on steep slopes; deep ploughing; leaving fields with low or no ground vegetation cover; and overgrazing. Landslides – the frequency and severity of which can be exacerbated by erosion – can also have disastrous effects on downslope agricultural production and human settlements. The dumping of large amounts of sediment into streams and rivers from erosion can affect aquatic biodiversity and water quality.[24]

It has been estimated that about one-third of the world's arable land has been lost to erosion in the last 40 years, and more than 10 million hectares are still being removed from production each year due to soil loss.[25] Important fractions of soils are lost when erosion occurs, and the quality of the remaining soil is also affected. Changes in structure and texture affect soil stability, water retention capacity and nutrient content. The loss of nutrients, fertilizers and pesticides due to erosion can affect crop emergence, growth and yield. In developing countries, soil erosion is closely linked to poverty because it affects people's livelihoods and well-being, making them more vulnerable to external shocks.

Trees can help reduce and prevent soil erosion in various ways (Box 2). Windbreaks and shelterbelts are the most widely used forms of agroforestry for soil erosion control. These systems also provide timber and other tree products and help increase crop productivity by reducing crop damage due to abrasive winds; enhancing pollination; and reducing soil evaporation. Trees can also be planted along contour lines and on erosion-control structures to help stabilize them. In alley-cropping systems, litter and mulch from prunings help protect soils and increase soil organic matter, increasing soil resistance to erosion. The presence of trees can lead to the progressive development of terraces through soil accumulation upslope of tree rows. Multistorey systems such as homegardens also possess an inherent capacity to prevent erosion, especially on slight to moderately steep slopes, due to their abundant litter and herbaceous cover.

BOX 2

Natural regeneration and agroforestry in degraded drylands in Niger

Farmer-managed natural regeneration or re-greening – a process in which farmers protect and manage trees that naturally regenerate on their land, rather than cut them down – has transformed 5 million hectares of degraded land into fertile farmlands in densely populated parts of Niger. It is estimated that farmers have established 200 million trees on their farms in the past 20 years, reversing desertification.

The trees, which were protected when small using low-cost techniques, act as windbreaks to counter erosion, fix nitrogen and provide mulch, thereby increasing both soil fertility and crop production. They are also a valuable source of fodder for livestock and wood for cooking and home construction. The integration of trees into farming systems thus contributes to the sustainable intensification and diversification of agricultural production while also increasing household incomes, improving food and nutrition security, and increasing the capacity of millions of farmers – who are reaping the benefits of land restoration through agroforestry – to cope with drought.

A major challenge in this process was developing policies and legislation that would stimulate farmers to invest in protecting and managing on-farm trees. Between 1998 and 2004, government tenure reforms relaxed the rules controlling tree harvests, tipping the balance towards farmer self-interest in regenerating and managing trees on their land.

Source: Reij, C. 2013. Learning from African farmers: how "re-greening" boosts food security; curbs climate change. Blog, 27 June (available at www.wri.org/blog/2013/06/learning-african-farmers-how-"re-greening"-boosts-food-security-curbs-climate-change). Accessed May 2017.

Agroforestry for increased water availability

Along with soil fertility, water availability is one of the most important constraints on crop production, especially in arid and semiarid climates. Soil degradation limits water availability in different ways, such as by increasing water runoff and reducing water infiltration and water retention capacity.

Although trees use water, agroforestry can have a positive effect on the water balance of soils. By increasing ground cover and soil organic matter compared with monocultures, agroforestry systems reduce water runoff and soil evaporation and increase water infiltration rates and water retention capacity, making more water available for plant production in all soil layers.[26]

All well-designed agroforestry systems with the capacity to prevent erosion and increase soil organic matter will improve the water balance. Trees on contour lines help stop water runoff, and windbreaks reduce soil evaporation by decreasing wind speed. Alley-cropping systems, homegardens and plantation–crop combinations all have higher rates of water infiltration than monocultures because of tree litter and the use of branch prunings as mulch.

Tree species with low water demand should be used in agroforestry systems when water is scarce to reduce competition between trees and crops for water. Reducing tree densities and making use of tree prunings will also reduce transpiration and thus tree water demand.

Agroforestry for improved livelihoods

Food insecurity and poverty have hampered the livelihoods of rural communities for decades and pose major challenges for sustainable development, especially in developing countries. Most rural poor are smallholders practising low-input agricultural production.

Agroforestry can help improve the livelihoods of the rural poor by producing food (e.g. fruit, nuts, edible leaves, sap and honey), fodder, timber, woodfuel, fibres and medicines. The adoption of agroforestry can save time in the harvesting of fodder and woodfuel, a particularly important benefit for women.

Agroforestry for food and nutrition security

Agroforestry can improve food and nutrition security, for example by supporting staple-crop production while providing edible tree products for home consumption; raising farmer incomes through the sale of tree products and surplus staples; producing woodfuel for cooking and heating; and supporting pollination services, which are essential for the production of some food plants.[27]

The diversification of food production provided by agroforestry also increases diet diversity, nutrient intake and the stability of access to food over time. On one hand, agroforestry uses the potential of a wide range of lesser-used indigenous foods found in forests and woodlands that are often richer than staple crops in micronutrients, vitamins, fibre and proteins. On the other, the diverse harvesting times of the various products in agroforestry systems can increase the year-round access of rural families to fresh food.

An ICRAF study[28] found evidence that, in times of shortage arising from crop failures or gaps between seasonal crop harvests, trees can provide foods rich in micronutrients, vitamins and proteins because of their differing phenologies. Because trees are often more resilient than annual crops to adverse weather conditions such as drought, they help feed people when crops fail. Many tree species are also important sources of medicines and natural remedies, which can help improve people's health. In addition to providing food and medicines for human consumption, leaves, fruit and other parts of many species of tree can serve as fodder for livestock, whose milk and meat can be important sources of protein. This fodder supply can be decisive in livestock production and survival, especially in dry seasons when other sources of forage are unavailable.

Agroforestry for income generation

Agroforestry can contribute to reducing poverty by generating income. Farmers receive higher returns on their labour and diversify their income sources through the increased production of agricultural and forest goods. Diversification helps stabilize revenues in the face of fluctuations in the prices obtained for commodity crops. The development of value chains for agroforestry-related tree products may create opportunities for small-scale forest-based enterprises and increase the number and diversity of jobs, especially for young people. For farmers, a common feature of monocultural crops is that labour demand is concentrated in short periods (such as for sowing, weeding and harvesting); diversification through agroforestry can help even out this demand over the year. In addition, the recognition of the ecosystem services provided by agroforestry offers a potential new source of income or other benefits for farmers through the establishment of incentives (either financial or in-kind).[29]

Agroforestry systems can grow high-value trees and understorey crops. Successful examples involving simple mixes of overstorey and understorey species are macadamia-nut trees with coffee in the understorey (Hawaii); laurel (*Cordia alliodora*, a timber tree) with coffee or cacao underneath (Central and South America); teak with patchouli (an essential oil) underneath (Indonesia); *Sesbania* spp. (a nitrogen-fixing shrub providing woodfuel, mulch and fodder) supporting and shading passion-fruit vines (East Africa); and *Faidherbia albida* and shea-nut trees grown in combination with sorghum and millet (West Africa).

Silvopastoral systems yield additional income when trees and tree products are harvested. Pine stands and nut and fruit orchards can be grazed to produce income as trees grow and become harvestable.

Planting avocado trees in Katbare, Ethiopia. ©TreesForTheFuture

The challenges for agroforestry in landscape restoration

3

Numerous examples worldwide show that landscape restoration is most likely to happen at a large scale when countries prioritize conservation, sustainable land use and land restoration and create an enabling environment for the implementation of restoration initiatives. A global assessment of land degradation and improvement, published in 2008,[30] estimated that land quality is improving on 16 percent of the world's land.

Planting monocultures of exotic tree species, which in the past was seen as a suitable means for restoring degraded land, is insufficient.[31] In contrast, forest and landscape restoration (FLR) is a long-term process that both enables the restoration of ecological functionality and enhances human well-being using a variety of land uses and diverse plant species. FLR requires good planning and the local adaptation of a mosaic of restoration options.

There are many ways to rehabilitate degraded landscapes, but few can restore biodiversity and ecosystems while also delivering food and income in the way that agroforestry does. Nevertheless, there are barriers to the uptake of agroforestry at the national and local levels.[32]

At the national level, the unclear status of land and tree resources, adverse regulations, an emphasis on commercial agriculture, a lack of coordination between sectors, and a lack of recognition by governmental institutions of the potential key role of agroforestry in contributing to sustainable development are important constraints on agroforestry. Improving policies and the institutional context, therefore, is at the heart of the agenda for agroforestry-based development. In particular, it is important to focus on tree and land tenure, which, in many countries, is often insecure, unclear, complex and fragmented.

Challenges at the local level include delayed returns on investment; underdeveloped markets and value chains for agroforestry products; limited knowledge of the advantages of agroforestry; and a lack of technical support and extension services to encourage farmers to adopt agroforestry. The delay in returns on investment is an especially important obstacle. The high opportunity costs of purchasing, planting, protecting and tending tree seedlings, and the long time before the first harvest, make it difficult for poor farmers to invest in trees. Moreover, because land tenure is insecure in many developing countries and trees are not always the property of farmers, such investments are risky. Low or no access to credit is an additional constraint, especially for women.

Agroforestry systems can be complex. Their implementation, therefore, requires support by specialized extension services that use participatory methods to teach farmers how to implement and manage agroforestry systems compatibly with the aim of restoring their lands and increasing agricultural production in the short and long terms.

Guatemala provides an example of the development of a policy designed to create an enabling environment in which rural communities can implement agroforestry successfully (Box 3).

BOX 3

PROBOSQUE – a law to stimulate restoration and tree planting in Guatemala

Guatemala is a megadiverse country, but its ecosystems are under threat from a range of stress factors, including deforestation. This situation prompted the Government of Guatemala to set a target to restore 1.2 million hectares of degraded land by 2045.

The National Strategy for Forest Landscape Restoration was approved in 2015, and a law called PROBOSQUE was enacted with the aim of supporting the protection, production and restoration of natural riparian forests, protected forests in upper watersheds, and mangrove and secondary (degraded) forests, and to establish 300 000 hectares of agroforestry systems.

Legal and practical guidelines for forest landscape restoration were prepared as part of this joint effort.

PROBOSQUE enables families without land titles to access its incentives, including for the provision of ecosystem services. Thus, landowners, tenants, cooperatives, indigenous communities and farmers on community lands will all be supported.

The increase in forest and tree cover is expected to create employment and stimulate rural economies while diversifying agricultural production and contributing to food security, energy supply, water quality and resilience to climate change.

Source: Sales, E., Rodas, O., Valenzuela, O., Hillbrand, A. & Sabogal, C. 2016. On the way to restore Guatemala's degraded lands: creating governance conditions. *World Development Perspectives*, 4: 16–18. DOI http://dx.doi.org/10.1016/j.wdp.2016.11.010

Villagers plant *Barringtonia* seedlings in Siem Reap Province, Cambodia, as part of an effort to restore a community forest. ©Feed the Future

Policy recommendations

4

Agroforestry systems have the potential to restore degraded lands, support livelihoods, improve food and nutrition security and reduce poverty, but constraints limit the adoption of these land-use systems in landscape restoration initiatives. The following policy recommendations would stimulate the scaling up of agroforestry in landscape restoration:

- **Greater recognition** of agroforestry systems as valuable options for restoring degraded landscapes is needed in restoration plans and policies. Because they provide a wide range of ecosystem services, including biodiversity conservation and carbon sequestration, agroforestry systems are also relevant to the implementation of international conventions such as the UNCCD, the United Nations Framework Convention on Climate Change, and the CBD.
- **Enabling policy environments** need to be put in place for the development and scaling up of traditional and improved agroforestry systems in landscape restoration projects. This means revising and reformulating unfavourable regulations and legal restrictions on agroforestry; improving coordination among the various sectors involved in agroforestry development; clarifying and securing land and tree tenure, taking into account the needs of women for better access to land and associated resources; and supporting agroforestry product value chains.
- **Incentive schemes** based on the role of trees in the supply of ecosystem services such as erosion control, enhanced biodiversity, water quality and carbon sequestration should be put in place to motivate farmers and landowners to favour agroforestry as a valuable option for increasing the productivity and profitability of their lands. Combined with upfront finance or other support to cover the often-significant start-up costs, such incentives would help farmers overcome investment barriers – especially delays in returns on investment in the period after tree establishment, in which trees yield little income but require resources for their upkeep.
- It is essential to **facilitate the development of local technical capacities** for the collection, production and distribution of crop and tree varieties and livestock breeds that can tolerate environmental extremes (e.g. drought, heat stress and salinity) in order to support local communities in adapting to climate change.
- **Access to information and training** should be provided to rural advisors and farmers, especially women and youth, to stimulate the adoption of agroforestry, taking advantage of both scientific and farmer knowledge.
- **Risk-mitigation mechanisms** are needed to attract more investment in agroforestry and to enable private investors to play their key role in realizing the sector's potential.

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Design by Marco Perri.

Forest and Landscape Restoration Mechanism

Restoring landscapes for enhanced livelihoods

Contact:

Douglas McGuire
Coordinator, Forest and Landscape Restoration Mechanism
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome, Italy

Douglas.McGuire@fao.org

I7374EN/1/09.17