Food and Agriculture Organization of the United Nations

245

ISSN 0041-6436

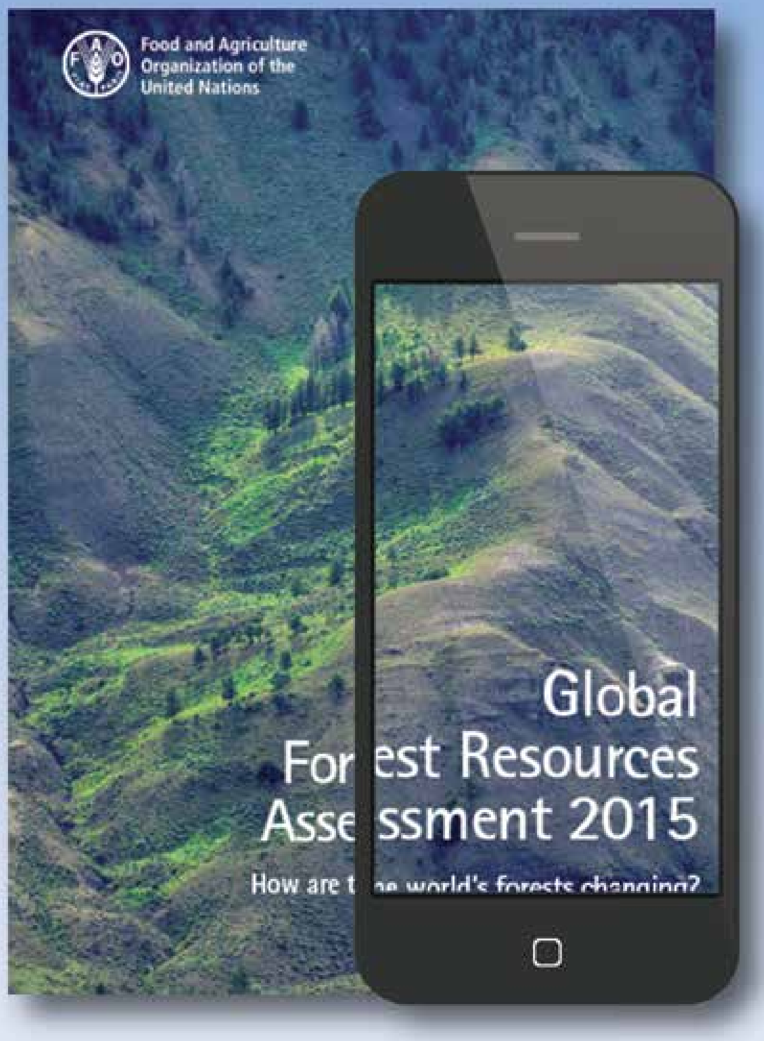
unasylva

An international journal of forestry and forest industries

Vol. 66 2015/3

FOREST AND LANDSCAPE RESTORATION

Enter the Global Forest Resources Assessment 2015 app competition!



Following the release of FAO's Global Forest Resources Assessment (FRA) 2015, FAO is launching the "25 years of forest change: Global Forest Resources Assessment 2015 app competition". Participants are invited to come up with mobile applications that can help better manage our forest resources and improve understanding of forests worldwide.

The app should be based on the FRA 2015 dataset, available via the Forest Land Use Data Explorer (FLUDE) online portal: **http://www.fao.org/forest-resources-assessment/explore-data/flude/en/**.

Target users include the scientific community, experts, policymakers and/or the general public.

Submissions will be accepted until 24:00:00 CET on 21 January 2016.

First prize is a US$2 000 paid assignment with FAO's Forestry Department to work on dissemination and outreach for the app. A tablet will be awarded to up to three runners-up.

The award ceremony will take place on 21 March 2016, the UN International Day of Forests.

Food and Agriculture Organization of the United Nations

For more information on how to enter, go to **http://www.fao.org/forest-resources-assessment/app-contest/en/**

Food and Agriculture Organization of the United Nations

245

ISSN 0041-6436

unasylva

An international journal of forestry and forest industries

Vol. 66 2015/3

Editor: S. Lapstun
Editorial Advisory Board: S. Braatz, I. Buttoud, P. Csoka, L. Flejzor, T. Hofer, F. Kafeero, W. Kollert, S. Lapstun, D. Mollicone, D. Reeb, S. Rose, J. Tissari, P. van Lierop
Emeritus Advisers: J. Ball, I.J. Bourke, C. Palmberg-Lerche, L. Russo
Regional Advisers: F. Bojang, P. Durst, A.A. Hamid, J. Meza

Unasylva is published in English, French and Spanish. Free subscriptions can be obtained by sending an e-mail to unasylva@fao.org. Subscription requests from institutions (e.g. libraries, companies, organizations, universities) rather than individuals are preferred to make the journal accessible to more readers.

All issues of *Unasylva* are available online free of charge at www.fao.org/forestry/unasylva. Comments and queries are welcome: unasylva@fao.org.

FAO encourages the use, reproduction and dissemination of material in this information product. Except where otherwise indicated, material may be copied, downloaded and printed for private study, research and teaching purposes, or for use in non-commercial products or services, provided that appropriate acknowledgement of FAO as the source and copyright holder is given and that FAO's endorsement of users' views, products or services is not implied in any way.

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO in preference to others of a similar nature that are not mentioned.

The publications reviewed in *Unasylva* are available on the FAO website (www.fao.org/publications) and can be purchased through publications-sales@fao.org.

Cover: Montana Conservation Corps (MCC) crews, made up of high school and college students from Wind River Indian Reservation, help Chicago Botanic Garden interns collect seeds for the Seeds of Success programme in the Lander Field Office area.
© BLM Wyoming

Contents

EDITORIAL

The publication of this issue of *Unasylva* coincides with two important events for forests. The 196 Parties to the United Nations Framework Convention on Climate Change have just convened at the Paris Climate Change Conference to broker a game-changing agreement on climate change. Also in Paris, the Global Landscapes Forum 2015 is hosting high-level discussions on the research and policy behind land-use issues. Forest and landscape restoration is a key piece in the puzzle.

The Oxford English Dictionary defines "restoration" as the "action of restoring a thing to a former state or position". Forest and landscape restoration (FLR), however, invests the word with a far greater role than that of simply returning to a past state. On a planet where the mark of human activity is almost ubiquitous, restoration is by necessity a concept that has to take into account human well-being and ongoing change.

In the opening article of this issue, Sabogal, Besacier and McGuire explore not only the concept, but also the approaches available – which vary considerably depending on location, scale, size and purpose – and the importance of identifying the drivers of forest and land degradation. Their article is followed by an overview by Laestadius, Buckingham, Maginnis and Saint-Laurent of the history of FLR. The movement has clearly evolved significantly from its origins in forestry in the 1990s to the ambitious target set by the 2011 Bonn Challenge Ministerial Roundtable of restoring 150 million hectares of the world's deforested and degraded lands by 2020.

FLR also means regarding the landscape as an integrated whole, which implies looking at different land uses together, their connections, interactions and a mosaic of interventions which, together, are expected to lead to restoration being more effective than a single land-use approach. In this light, Janishevski, Santamaria, Gidda, Cooper and Brancalion explore the role of protected areas, emphasizing that these areas must not be seen in isolation, but rather maintained and restored together with other parts of the landscape to ensure connectivity between areas, notably to ensure biodiversity conservation in the face of climate change.

Restoration initiatives must also ensure that appropriate and genetically diverse planting material is chosen for planting sites. If this is not the case, restoration may fail, although this may become apparent only long after the initiation of the activity, or in the wake of exceptional events, as demonstrated by Thomas, Jalonen, Loo and Bozzano.

Several articles look at the specificities of different regions and biomes. Berrahmouni, Parfondry, Regato and Sarre examine approaches to restoring degraded forests and landscapes in drylands, illustrated by a case study in Ica, Peru. Sacande, Berrahmouni and Hargreaves present the experiences of Africa's Great Green Wall for the Sahara and the Sahel Initiative, and the way in which it builds upon community involvement.

Appanah, Shono and Durst also emphasize the importance of local participation in their overview of restoration activities in Southeast Asia, an area that has witnessed both resounding successes and failures. The restoration of the Baekdudaegan area, a mountain chain that runs through the Korean peninsula, has also encountered numerous hurdles, as described by Cho and Chun, but has made important progress and could also provide a basis for regional collaboration.

Daoxiong, Wenfu, Zhilong and Dongjing focus specifically on reforestation, presenting experimental approaches in China to transform the country's planted forests and degraded lands into close-to-nature forests.

The case of southern Europe, an area that has been subjected to significant degradation and climate-related stressors, is examined in detail by Coello, Cortina, Valedecantos and Varela, who emphasize the need to boost support for restoration programmes to ensure success.

Bamboo could be an interesting solution in some areas, as argued by Rebelo and Buckingham, who explore its potential in tackling the challenges of restoration, notably through innovative approaches involving the private sector. In the final article, Gutierrez and Keijzer look more broadly at the funding options for FLR, also focusing on how to engage the private sector.

In order to succeed in the long term, forest and landscape restoration initiatives will need to successfully engage a range of stakeholders, from policymakers to local communities and from governments to private actors. This issue maps out some of the progress that has already been made, and the challenges that lie ahead. ◆


©FAO/GIANLUIGI GUERCIA

Forest and landscape restoration: concepts, approaches and challenges for implementation

C. Sabogal, C. Besacier and D. McGuire

There is an urgent need to accelerate the recovery of degraded ecosystems for the benefit of humans and nature – this requires a comprehensive and intersectoral approach.

César Sabogal is Senior Forestry Officer in charge of Sustainable Forest Management at FAO.
Christophe Besacier is Forestry Officer in the Forest and Landscape Restoration Mechanism team in FAO's Forestry Department.
Douglas McGuire is Senior Forestry Officer in charge of coordination of the Forest and Landscape Restoration Mechanism team in FAO's Forestry Department.

CONCEPTS

Forest and land degradation is a serious problem worldwide, particularly in developing countries. Approximately one billion people live in degraded areas, which represent 15 percent of the Earth's population, and one third of the world's population is considered to be affected by land degradation.[1]

Land degradation is generally defined as a "persistent decline" in the provision of goods and services that an ecosystem provides, including biological and water-related goods and services as well as land-related social and economic goods and services (FAO/LADA, n.d.). *Forest degradation* refers to a reduction of the capacity of a forest to provide goods and services (FAO, 2011).

Continued forest and land degradation poses serious obstacles to the elimination of poverty and hunger and the reversal of biodiversity loss in many parts of the world today, as well as to the ability of farmers and local communities to adapt to the impacts of climate change.

[1] According to ISRIC World Soil Information (ISRIC, n.d.), land degradation costs an estimated €30 billion annually worldwide and affects more than a billion people, especially in drylands.

Above: Lowlands village on the outskirts of Hlotse, Lesotho, 2010


©FAO/GIULIO NAPOLITANO

Farmer herding cattle, Higo village, Ethiopia, 2010

This degradation process also increases competition for scarce resources, with possible conflicts between users. These in turn threaten the livelihoods, well-being, food, water and energy security, and resilience (defined as the ability of people to adapt to climate change) of millions of people. Reversing forest and land degradation is therefore an imperative task for humankind.

Restoration is defined as any intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state (IPBES, n.d.). Restoration efforts should be planned at the landscape level with the aim of re-establishing ecological integrity[2] and supporting human well-being (Maginnis and Jackson, 2003).

A *landscape* can be regarded as the heterogeneous mosaic of different land uses (agriculture, forestry, soil protection, water supply and distribution, biodiversity conservation, pasture provision, etc.) across a large area of land or a watershed. A *landscape approach* seeks to better understand and recognize the interactions between various land uses and stakeholders by integrating them in a joint management process (GLF, 2014). Natural resources can be better managed when viewed from a broader perspective, considering and involving the perceptions, needs and interests of all stakeholders, including local communities and individual land users. Landscape approaches are increasingly seen as essential in developing sustainable land-use and livelihood strategies in rural areas (FAO, 2012).

Forest and landscape restoration (FLR) is an emerging concept that refers to an approach involving stakeholders in all affected land-use sectors and applying participatory decision-making processes. According to the most consistent existing definition, proposed by the Global Partnership on Forest and Landscape Restoration (GPFLR), FLR 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" (GPFLR, n.d.). FLR seeks a balance between restoring ecosystem services related to wildlife habitats and biodiversity, water regulation, carbon storage and more, and supporting the productive functions of land for agriculture and other related uses (McGuire, 2014).

[2] "Ecological integrity" has no uniformly accepted definition. According to one interpretation (Steinhoff, 2013), an ecosystem has ecological integrity if it is either pristine, i.e. entirely free of human influence, or has been only minimally influenced by humans. An ecosystem with ecological integrity may serve as a standard or benchmark for assessing the degradation of natural ecosystems by human activities.

©FAO/GIUSEPPE BIZZARRI

Farmers control soil erosion through crop cultivation, Honduras

PLANNING RESTORATION

The implementation of FLR initiatives can vary considerably in temporal scale, size and purpose. It can serve one single landscape function or objective (e.g. adapting/mitigating climate change or biodiversity conservation) or it may be carried out for *multiple combined objectives*. These might include mitigating land degradation and establishing sustainable land-use and management practices, enhancing land productivity, supporting livelihoods, contributing to poverty alleviation (e.g. by supplying a variety of forest and agricultural products to local communities), conserving biodiversity and providing other environmental services (e.g. water and soil protection), and creating landscapes that sequester large quantities of carbon and are resilient to adverse change. The objective, strategy and action plan for landscape restoration have to be customized to the specific conditions of the place, including its biophysical conditions and its stakeholders, and taking into account their interests and the decisions they make (Van Oosten, 2013).

The review (identification and analysis) of the *agents and drivers of degradation* is an essential step before embarking on any restoration work. Most indirect or direct drivers of forest and landscape degradation are human activities that negatively impact upon lands and result in the loss of biodiversity, fertile lands and carbon stocks. Agriculture (in particular, commercial agriculture) is estimated to be the main driver for around 80 percent of deforestation[3] worldwide. Mining, infrastructure and urban expansion are also important drivers of forest and land degradation. Findings on global patterns of forest degradation indicate that (commercial) timber extraction and logging activities account for more than 70 percent of total forest degradation in Latin America and subtropical Asia. Fuelwood collection, charcoal production, subsistence agriculture, uncontrolled fire and livestock overgrazing in forested landscapes are also important drivers of forest and landscape degradation in several developing countries, particularly in Africa (Kissinger *et al*., 2012).

[3] The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold (FAO, 2011).

Successful restoration initiatives are likely to be based on *integrated land-use planning* which means: (i) community-based landscape planning and decision-making; (ii) effective intersectoral cooperation and coordination among government agencies at the national, subnational and local levels; (iii) the strengthening of local institutions to better manage conflicts over land use and tenure; and (iv) improved policies for integrated management (e.g. on agroforestry) (FAO, n.d.).

A *mosaic approach to restoration* that considers several types of land use over a broad landscape is accepted today as the best-suited for restoring up to three quarters of the world's degraded landscapes (GPFLR, WRI, South Dakota State University and IUCN, 2011). In this approach, the scale is large enough to ensure a significant impact, and multiple objectives can be addressed, both to enhance ecosystem protection and improve the productive capacity of the landscape.

Priority areas for FLR include unproductive or abandoned agricultural land, deforested areas converted to grasslands, brush lands, scrublands or barren areas, and degraded forests. Forests can be restored and rehabilitated by protective measures (e.g. protection from fire or overgrazing and erosion control), measures to accelerate natural regeneration (e.g. through direct seeding or by planting seedlings in degraded primary or secondary forests), measures to assist natural regeneration (e.g. through weed control on degraded lands and marginal agricultural sites), and the planting of native or introduced trees in single-species or mixed-species plantations, in agroforestry production systems and as trees outside forests. Figure 1 illustrates relevant option categories for FLR work, distinguishing land use and land subtype.

APPROACHES TO WORKING WITH FOREST AND LANDSCAPE RESTORATION

The FLR concept is based on intersectoral and comprehensive approaches that include multiple action areas such as: assessment of landscape degradation (including identification of main agents and drivers of degradation) and restoration opportunities; enabling environment (policies, regulations and laws); institutional setting; governance issues (e.g. tenure, right to use of natural resources, local community and its involvement, etc.); technologies and approaches; private-sector investment; resource mobilization; capacity development, extension and dissemination; and research needs (Figure 2 and Table 1). The idea is to ensure that different action areas are connected as the process moves forward.

1
FLR options framework

Land use	Land subtype	General category of FLR option	Description
Forest land Land where forest is, or is planned to become, the dominant land use ➨ **Suitable for wide-scale restoration**	If the land is without trees, there are two options:	1. Planted forests and woodlots	Planting of trees on formerly forested land. Native or introduced species planted for various purposes, fuelwood, timber, building, poles, fruit production, etc.
		2. Natural regeneration	Natural regeneration of formerly forested land. The site may be highly degraded and no longer able to fulfil its past function, e.g. agriculture. If the site is heavily degraded and no longer has native seeds, some planting will probably be required.
	If the land consists of degraded forests:	3. Silviculture	Enhancement of existing forests and woodlands and stocking, e.g. by reducing fire and grazing and by liberation thinning, enrichment planting, etc.
Agricultural land Land that is managed to produce food ➨ **Suitable for mosaic restoration**	If the land is under permanent management:	4. Agroforestry	Establishment and management of trees on active agricultural land, either through planting or favouring natural regeneration, to improve crop productivity, provide dry season fodder, increase soil fertility, enhance water retention, etc.
	If the land is under intermittent management:	5. Improved fallow	Establishment and management of trees on fallow agricultural lands to improve productivity, e.g. through fire control, extending the fallow period, etc., with the intention that eventually this land will revert back to active agriculture.
Protective land and buffers Land that is vulnerable to, or critical in safeguarding against, catastrophic events ➨ **Suitable for mangrove restoration, watershed protection and erosion control**	If the land is degraded mangrove:	6. Mangrove restoration	Establishment or restoration of mangroves along coastal areas in estuaries.
	If it is other protective land and buffer:	7. Watershed protection and erosion control	Establishment and restoration of forests on very steep sloping land, along water courses, in areas that naturally flood and around critical water bodies.

Source: GPFLR (n.d.), adapted from IUCN (2014).

TABLE 1. Key areas of intervention and some important issues to address in forest and landscape restoration planning and implementation

Key area of intervention	Factors or issues to take into account
Assessment of landscape degradation and restoration opportunities	• Decide on the most appropriate assessment methodologies to use (e.g. ROAM,[1] LADA,[2] etc.). • Identify degraded lands and the best opportunities for successful restoration efforts. • Identify main agents and drivers of degradation within landscapes. • Assess the ecological conditions, social-cultural dynamics and other enabling factors. • Carry out stocktaking of successful interventions. • Analyse and evaluate costs and benefits of selected restoration options and carry out a risk assessment of those options for investors.
Enabling environment	• Analyse policies, laws and regulations across different sectors. Are they adequate? Are they complementary/conflicting? • Support drafting, revision and/or harmonization of laws/policies/sectoral programmes and identify specific support, activities and projects to create a more enabling environment.
Institutional setting	• Identify relevant land-use sectors and stakeholders for FLR (forestry, agriculture, livestock/rangeland, energy, mining, etc.). • Support planning processes that are underway (e.g. climate-change national strategy, biodiversity national strategy, national strategy for rural development, etc.). • Consider all relevant entry points as FLR can be an effective package to generate and share a range of benefits (e.g. biodiversity, food security, climate mitigation and adaptation, livelihoods, poverty alleviation, etc. • Identify/support existing mechanisms/platforms that allow different sectors/stakeholders to engage in dialogue. • Identify and leverage existing partnerships.
Governance issues	• Assess land-tenure issues and try to secure tenure, especially for local stakeholders, as a key issue to allow investments in FLR. • Identify barriers to people's participation. • Analyse decision-making processes. • Facilitate engagement of all relevant stakeholder groups.
Technologies and approaches	• Carry out stocktaking of existing technologies and approaches for sustainable land use (reforestation, assisted natural regeneration, agroforestry, climate-smart agriculture, agroecology, etc.). • Build on successful experiences and approaches already carried out. • Set up a portfolio of cost-effective and ecologically robust restoration techniques. • Identify knowledge gaps.
Capacity development and extension	• Identify capacity-development needs at the individual and organizational level and propose relevant strategies to meet these needs. • Build capacity-development programmes for relevant stakeholders to undertake planning, implementation and evaluation of FLR efforts. • Develop networks/knowledge platforms (national/regional) between practitioners and extension services in order to disseminate good practices. • Support the establishment and continued capacity strengthening of networks of practitioners and extension services.
Resource mobilization	• Estimate the resources already available through existing national/subnational programmes/projects. • Elaborate national action plans or national strategies as the basis for building trust with donors in terms of national commitment to FLR. • Integrate FLR into state budgets and public investment funds. • Develop monitoring systems for FLR expenditures and mechanisms for collecting data on the costs and benefits of FLR. • Devise a coordinated approach to informing/sensitizing potential donors (multilateral, bilateral, foundations, etc.) and support the development of new project proposals. • Mobilize innovative sources of funding through mechanisms such as climate finance instruments and/or payment for environmental services and develop incentive packages that include economic and non-economic benefits. • Design, adapt and implement national and local financing mechanisms for FLR, in particular by promoting the development of financial instruments at the local level (e.g. local development funds, microfinance instruments, credit lines in local private banks), with positive incentives for local stakeholders to promote sustainable FLR investments. • Use these financing instruments to implement public incentive schemes (e.g. payments for ecosystem services) and couple these schemes with investments in sustainable value chains to ensure a long-term, self-sustaining financing strategy.
Private-sector investment	• Increase engagement with the private sector, especially with pioneer private-impact funds and other innovative initiative funds as key partners in the FLR investment continuum (Figure 3). • Understand the scope of private-sector involvement in FLR already underway in the country and build a legal and regulatory framework that promotes landscape "readiness for investments" and attracts investors to FLR. • Facilitate the dialogue between the private sector and other stakeholders in order to decrease transaction costs for private-sector investments. • Develop a pipeline of bankable restoration projects and raise the awareness of the private sector about FLR opportunities in key value chains (marketplace). • Foster favourable conditions for public–private partnerships and promote risk-mitigation mechanisms to engage FLR investors at scale.
Information dissemination and research needs	• Facilitate regular access to relevant information with practical knowledge and experiences targeting varied audiences. • Identify (biophysical, socioeconomic, etc.) gaps in knowledge that research institutions could address more effectively. Emphasize research geared to innovative solutions for local stakeholders. • Develop robust indicators adapted to the local/national context and develop consistent monitoring systems in order to improve the effectiveness of FLR efforts.

[1] Restoration Opportunities Assessment Methodology (ROAM, IUCN).

[2] Land Degradation Assessment in Drylands (FAO).

Source: Authors.

2
Key areas of intervention for forest and landscape restoration

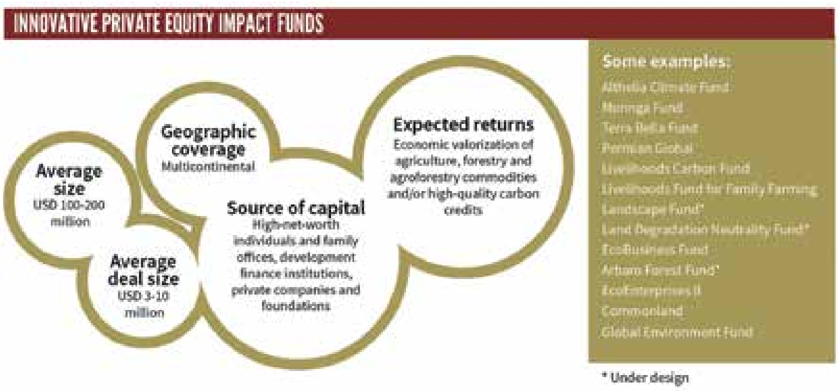
CONCLUSIONS

The articles in this issue of *Unasylva* provide a number of important considerations for FLR implementation in diverse categories of degraded landscapes, illustrating the complexity of FLR issues.

A few general conclusions can be drawn from the multiple experiences, and are described below:

- *The major causes of forest and land degradation vary among regions and specific contexts*. It is critical to take into account past trends and foresee future biophysical conditions – particularly with respect to the anticipated effects of climate change on temperature, water availability and yield potential – as well as human pressure projections, to ensure the sustainability of any FLR project in the long term. This includes assessing the vulnerability of lands and systems to the effects of climate and of environmental and socioeconomic changes in order to understand and address the potential risks of investments in FLR.
- *Balancing public goods and services provision with private benefits is key to ensuring the long-term sustainability of the restored landscapes*. Poor marketing and financial arrangements can prevent large-scale investment in trees and land restoration whereas innovative financial tools that provide early rewards can be drivers of investment in FLR. Ex-post and ex-ante cost–benefit analyses of FLR investments and risk-mitigation mechanisms are needed to engage FLR investors at scale, particularly private investors and impact funds
- *The success of past restoration efforts remains poorly documented and disseminated*. This missed opportunity to learn from past experiences and to improve practices for better success rates and more efficient resource use in future restoration projects is highlighted by several authors in this issue of *Unasylva*. Taking this into account, FLR initiatives should begin with the questions "What is it we want to restore?'', "What are the techniques available for restoration?''

3
Innovative private equity impact funds



Source: FAO, 2015b.

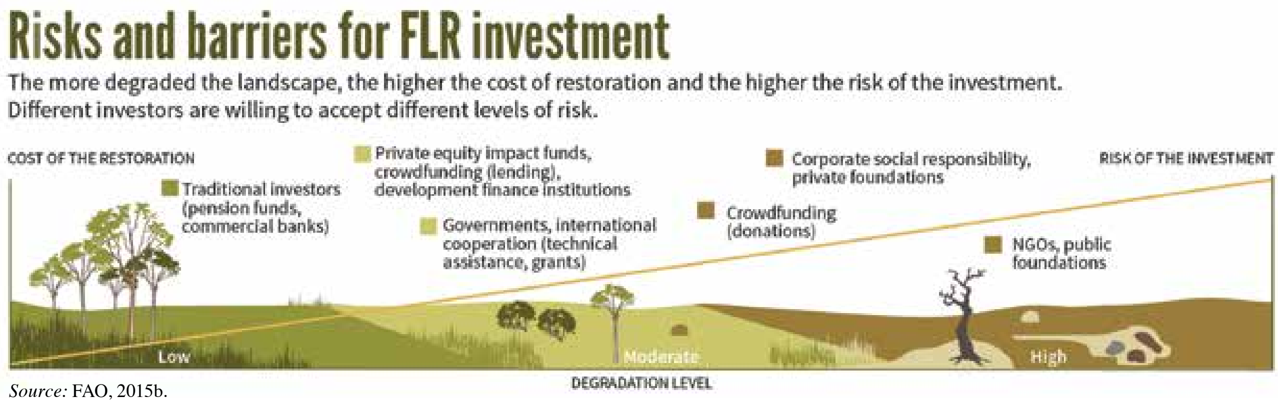
and "How does policy need to be adapted to facilitate restoration efforts at national, subnational and local levels?''

- *Not all stakeholders share the same views on preferred sites or expected outcomes from restoration efforts.* There are many examples of projects that have failed because local communities were not properly involved in the planning, design and implementation of the project. A better understanding of the socioeconomic aspects is needed, to establish whether the purposes of the restoration projects are in line with the motivations, expectations, pressures and needs of the concerned stakeholders. Issues associated with policies, institutions, and social issues are often more important than technical issues. Crucial aspects of policy relating to tenure and equity are often unfavourable, restrictive and lacking in incentives for communities to undertake FLR initiatives. Investments in FLR require good governance with a reliable, enabling policy environment, responsible regulation and reliable mechanisms to resolve conflicts between stakeholders.
- *Often insufficient consideration is given to the selection of appropriate planting material by restoration practitioners around the world.* Use of inadequate planting material may become even more common as a consequence of the limited restoration experience of the many new actors emerging in response to the enormous restoration goals worldwide. Natural regeneration and/or assisted natural regeneration, which are simple and effective restoration measures that require little investment, do not appear to be sufficiently promoted and, when plantation is required, the choice of genetic material and use of native species (trees, shrubs, and grasses) should aim to maximize genetic diversity as well as to enhance resilience and sustainable livelihoods.
- In spite of the growing international recognition of the importance of ecological restoration, *large-scale FLR programmes have only just started to be designed*, which limits our understanding of the real need and key factors of success of such initiatives for complementing biodiversity conservation in protected areas.
- All FLR investors (public or private) expect a return (financial, social or environmental) on their investment. Potential ecosystem and social benefits such as improved carbon sequestration, biodiversity conservation, and improved livelihoods and well-being of farmers or landowners are either underestimated or not properly valued as part of the opportunity costs.

©FAO/YASUYOSHI CHIBA

©FAO/YASUYOSHI CHIBA

Above: Village, Betroka Region, southern Madagascar, 2011
Below: Cultivated fields, Betroka Region, southern Madagascar, 2011



Source: FAO, 2015b.

4
Risks and barriers for FRL investment

The resulting underestimation of the benefits of restoration makes related investment risks appear greater, which can discourage investors (Figure 4). Cost–benefit analyses and *improved marketing are required to demonstrate that investments in FLR should be considered in some cases as* "*impact investments*",[4] *in particular in more degraded landscapes* where the only direct economic benefits may not be attractive enough for private investors. ◆

References

FAO. 1995. Planning for sustainable use of land resources. Towards a new approach. *FAO Land and Water Bulletin*, 2. Rome.

FAO. 2011. *Assessing forest degradation. Towards the development of globally applicable guidelines*. Forest Resources Assessment Working Paper No. 177. Rome.

FAO. 2012. *Mainstreaming climate-smart agriculture into a broader landscape approach*. Background Paper for the Second Global Conference on Agriculture, Food Security and Climate Change. Hanoi, Vietnam, 3–7 September 2012.

FAO. 2015a. *Global guidelines for the restoration of degraded forests and landscapes in drylands: building resilience and benefiting livelihoods*. Forestry Paper No. 174. Rome.

FAO. 2015b. *Sustainable financing for forest and landscape restoration*. Rome, FAO, and Global Mechanism of the UNCCD.

FAO. n.d. Land resources website (available at http://www.fao.org/nr/land/sustainable-land-management/integrated-approach-to-slm/en/).

FAO/LADA. n.d. Land Degradation Assessment in Drylands website (available at http://www.fao.org/nr/lada/index.php?option=com_content&view=frontpage&Itemid=75&lang=en).

GIIN. 2013. Global Impact Investing Network website (available at http://www.thegiin.org/about). Accessed 15 November 2015.

GLF. 2014. Global Landscapes forum website (available at http://www.landscapes.org/glf-2014/about/).

GPFLR. n.d. Global Partnership on Forest Landscape Restoration website (available at http://www.forestlandscaperestoration.org/).

GPFLR, WRI, South Dakota State University & IUCN. 2011. *The Bonn Challenge: A world of opportunity* [brochure]. Bonn, Germany.

IPBES. n.d. Intergovernmental Science–Policy Platform on Biodiversity & Ecosystem Services website (available at http://www.ipbes.net/).

ISRIC. n.d. World Soil Information website (available at http://www.isric.org/global-issues).

IUCN. 2014. *Assessing forest landscape restoration opportunities at the national level: A guide to the Restoration Opportunities Assessment Methodology* (ROAM). Working Paper (Road-test edition). Gland, Switzerland, IUCN.

Kissinger, G., Herold, M. & De Sy, V. 2012. *Drivers of deforestation and forest degradation. A synthesis report for REDD+ policymakers*. Vancouver, Canada, Lexeme Consulting.

Maginnis, S. & Jackson, W. 2003. *The role of planted forests in forest landscape restoration*. UNFF Intersessional Experts Meeting on the Role of Planted Forests in Sustainable Forest Management, 25–27 March 2003, New Zealand.

McGuire, D. 2014. FAO' s Forest and Landscape Restoration Mechanism. *In* J. Chavez-Tafur & J. Roderick Zagt, eds. *Towards productive landscapes*. Wageningen, Netherlands, Tropenbos International.

Steinhoff, G. 2013. Ecological integrity in protected areas: two interpretations. *Seattle Journal of Environmental Law*, 3: 155.

Van Oosten, C. 2013. Forest landscape restoration: Who decides? A governance approach to forest landscape restoration. *Natureza & Conservação*, 11(2): 119–126. ◆

[4] "Impact investments" refers to investments "made into companies, organizations, and funds with the intention to generate a measurable, beneficial social or environmental impact alongside a financial return" (GIIN, 2013).

Before Bonn and beyond: the history and future of forest landscape restoration

L. Laestadius, K. Buckingham, S. Maginnis and C. Saint-Laurent

An overview of the restoration movement, from its origins in forestry in the late 1990s to the landmark Bonn Challenge Ministerial Roundtable in 2011, highlighting the need to transform political commitment into action on the ground.

Lars Laestadius is Senior Associate at the World Resources Institute.
Kathleen Buckingham is Research Associate with the World Resources Institute.
Stewart Maginnis is Global Director of the Global Forest and Climate Change Programme, International Union for Conservation of Nature.
Carole Saint-Laurent is Deputy Director of the Global Forest and Climate Change Programme, International Union for Conservation of Nature.

In the late 1990s, forest protection and the sustainable management of working forests were the primary issues that dominated the international forest agenda and shaped national policy and action (IUCN and WWF, 2002). Reforestation and tree planting tended to be considered in terms of industrial plantations or community-level woodlots, with the former often proving controversial (Cossalter and Pye-Smith, 2003). Early advocates of a "landscape approach" emphasized the importance of approaching land management as something that is broader and more comprehensive than a set of site-level technical interventions, and in particular the opportunity that this presented for balancing trade-offs and delivering multiple benefits simultaneously at the landscape level (Maginnis *et al*., 2004). Central to this thinking was not only the need to safeguard existing forest goods and services in so-called "intact landscapes" but also the need to restore them where they were lacking.

The term "forest landscape restoration" (FLR) was coined in 2000 at a forestry meeting in Segovia, Spain (IISD, 2002; IUCN and WWF, 2000), which defined it as: "a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes" (IISD, 2002). The limitation that the process should be planned has since been dropped and some actors

Landscape in Ethiopia

© AARON MINNICK

(including FAO) have started to use the term “forest and landscape restoration” without changing the definition.

The inclusion of the word “landscape” was an important step towards broadening the concept of “forest restoration”, as it explicitly implied the return of multiple forest and tree-related goods and services (Sayer *et al*., 2003). Forest landscape restoration therefore recognized a matrix of landscape options across forestry and agriculture (Laestadius *et al*., 2011), and trees outside as well as within forests (FAO, 2000). It was envisioned from the outset as a framework that could be applied across a range of land uses. The emphasis on restoring ecosystem services to meet societal needs meant that future options were left open in order to deal effectively with the uncertainties of climatic, economic and social change, and that FLR was explicitly not a call to return to past visions and patterns of land use (Laestadius *et al*., 2011).

The meeting in Spain was the first milestone of many in the development of forest landscape restoration. It was followed by a workshop in Heredia, Costa Rica, in March 2002 (IUCN, 2002), organized by the International Union for Conservation of Nature (IUCN) and supported by the International Tropical Timber Organization (ITTO) (amongst others), which stressed that forest landscape restoration was more than just an interesting idea but had substance (Maginnis and Jackson, 2002). However, the challenge and scope of landscape-level decisions required new partners and approaches to doing business (IISD, 2002).

Prior to the Segovia meeting, IUCN and the WWF had promoted a landscape approach to forest restoration among their common strategic objectives at the international level, and this agenda was being steadily taken up at regional levels (Lamb and Gilmour, 2003). Attention was given to documenting the experiences of field projects that had tested aspects of landscape restoration approaches (Mansourian *et al*., 2005). Prompted by preparations for the 10th anniversary of the Earth Summit, in 2001 IUCN began promoting the idea of setting up a global partnership on FLR, which was subsequently registered at the World Summit on Sustainable Development (WSSD) in 2002 as the Global Partnership on Forest Landscape Restoration (GPFLR).

The early development of the landscape approach is not specific to the forestry sector. The broad use of landscape planning tools (geographical information systems) in developing countries during the 1990s started to introduce a broader landscape perspective to sectoral planning processes. Early thinking on FLR was heavily influenced by experience in Costa Rica (Janzen, 2000), which demonstrated the importance of secondary forest regeneration, and in the United Republic of Tanzania (Wenger *et al*., 2005), which showed the benefits of restoration at scale. Nevertheless, international organizations continued to focus mainly on plantations and reforestation (Cossalter and Pye-Smith, 2003). In light of this, IUCN produced a series of discussion papers on plantations (Maginnis and Jackson, 2002), recommending that the World Bank include “a landscape approach” in their “forest policy review” and consider investment in forest restoration projects based on a total economic valuation (Maginnis *et al*., 2004). At the same time, IUCN, WWF, the Center for International Forestry Research (CIFOR) and ITTO conducted research into secondary and degraded forests (ITTO, 2002).

To align global restoration activities, the partnership concept was further developed during a consultative meeting organized by the Forestry Commission of Great Britain, IUCN and WWF in Edinburgh, United Kingdom, in September 2002. The GPFLR, having been registered as a WSSD partnership, was then launched at a session of FAO’s Committee on Forestry in March 2003 (IISD, 2005). The partnership aimed to support and influence global policy and encourage national action (Van Oosten, 2009). In order to do so, the GPFLR held the first global Forest Landscape Restoration Implementation Workshop in April 2005 in Petrópolis, Brazil, co-hosted by the Governments of Brazil and the United Kingdom (IISD, 2005). The workshop resulted in the “Petrópolis Challenge”: “to restore forest landscapes to benefit people and nature and contribute to reversing the trends of forest loss and degradation” (IISD, 2005). Key elements in meeting the challenge were to develop the GPFLR and build a learning network around restoration (Saint-Laurent, 2015). The Challenge also called for FLR to be linked with national-level development processes. The workshop was a country- and organization-led initiative of the United Nations Forum on Forests (UNFF). The Governments of the United Kingdom and Brazil presented the outcomes of the workshop to the 5th session of the UNFF in May 2005, where they shaped the Ministerial Dialogue on Restoring the World’s Forests held during this UNFF session, the first ministerial-level event to address this issue (UNFF, 2005). Drawing on the outcomes of the Petrópolis Workshop, GPFLR members also provided input into forest-related deliberations for the UN Convention to Combat Desertification (UNCCD), the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC), ITTO, Tehran Process on Countries with Low Forest Cover, and other relevant policy processes at the international and regional levels, including the Millennium Development Goals and follow-up to the World Summit on Sustainable Development (Saint-Laurent, 2005).

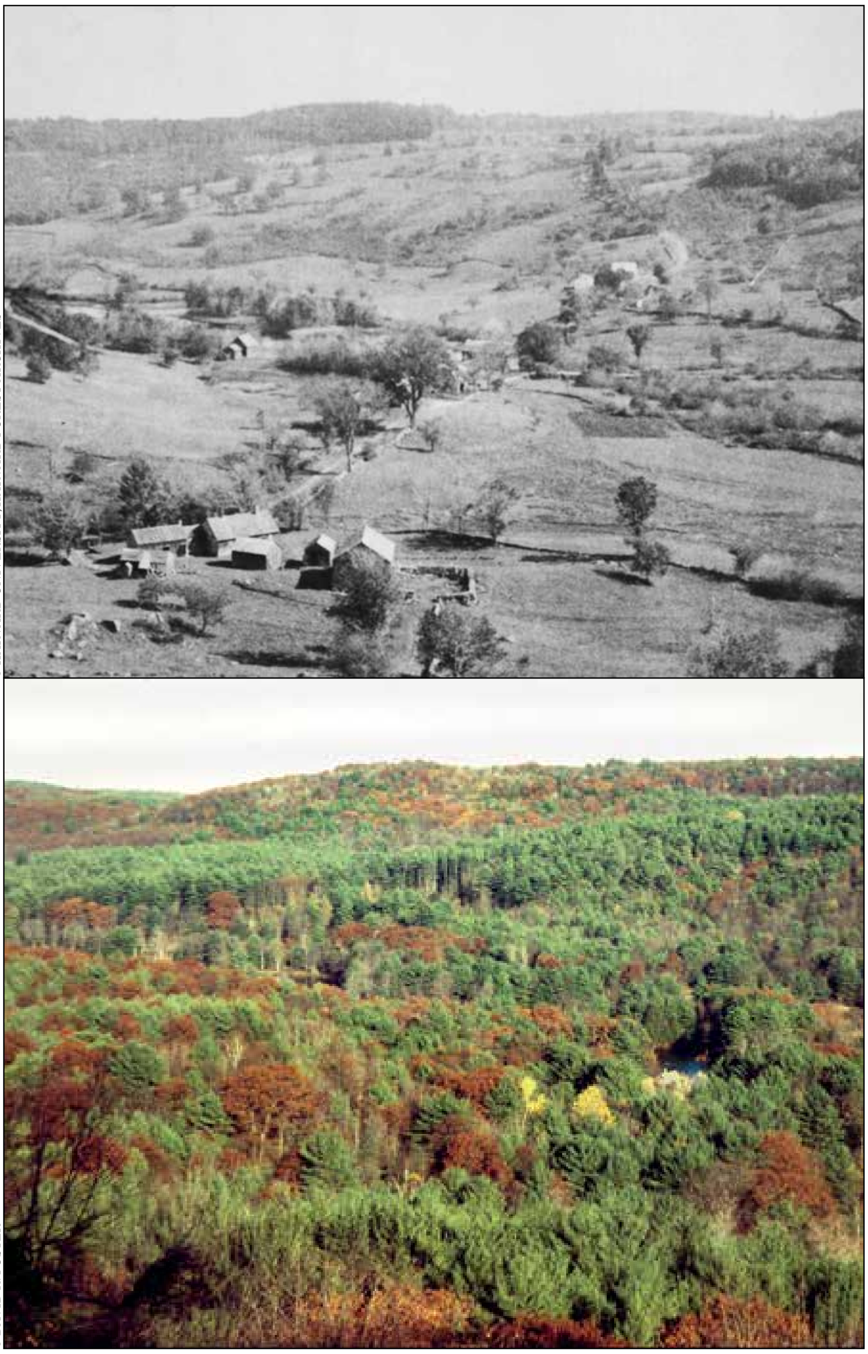
UNDERSTANDING THE SCALE OF THE RESTORATION OPPORTUNITY

While the issue of FLR garnered significant stakeholder support, there was a gap in understanding regarding its potential scope. In November 2009, a High-Level Roundtable on Forest Landscape Restoration was convened in London by the Government of the United Kingdom and IUCN to bring together a group of ministers and other high-level representatives from government, the private sector, indigenous peoples' organizations and civil society to produce the London Challenge, which focused on the themes of climate change and people, and outlined a work plan for the GPFLR (Saint-Laurent, 2015). In preparation for this event, the GPFLR commissioned the World Resources Institute (WRI), IUCN and South Dakota State University to estimate the global restoration opportunity. Preliminary results of a comparison between potential and actual forest extent suggested that over 1 billion ha of deforested and degraded forest landscapes provided restoration opportunities (Röttgen and Khosla, 2011). The Bonn Challenge target of 150 million ha represents 15 percent of this estimate, consistent with the Aichi Biodiversity Target 15 of the CBD, which calls for restoration of 15 percent of degraded ecosystems (CBD, 2010).

In September 2011, at the invitation of the German Government and IUCN, representatives of organizations and countries engaged in GPFLR came together with world leaders in Bonn to demonstrate support for forest landscape restoration and for the first time to commit to an ambitious global target (GPFLR, 2013). At this event, the GPFLR launched the "Landscapes of Opportunity" map based on a refined analysis of the global restoration opportunity by WRI, IUCN and South Dakota State University, with input from other partners such as the World Bank's Program on Forests (PROFOR) and the Forestry Commission of Great Britain. The refined analysis estimated the global restoration opportunity at more than 2 billion ha (Laestadius *et al*., 2011).

The updated map had a pivotal effect on the emerging restoration movement by visualizing and quantifying the global restoration opportunity, and by showing that opportunities for restoration may be found in most countries. It also highlighted where the opportunity was greatest – in tropical and temperate areas, with more than 1.5 billion ha best suited for mosaic-type restoration interfacing directly with non-forest land uses, and another 0.5 billion for more conventionally understood wide-scale forest restoration (Figure 1) (Laestadius *et al*., 2011). By putting a number to the size of the global restoration opportunity, the map made it possible to formulate the Bonn Challenge, i.e. a quantitative goal for FLR.

The Bonn Challenge aspires to have 150 million ha of land under restoration by 2020 and is an implementation vehicle



© HARVARD UNIVERSITY, HARVARD FOREST ARCHIVES

© DAVID R. FOSTER

Landscape before and after restoration, United States of America

Source: Minnemeyer *et al*., 2011.

1
The map shows areas believed to provide opportunities for different types of forest landscape restoration and deserving of further analysis at the national scale. Wide-scale restoration aims to restore dense forests to the landscape. This type of restoration was thought most feasible in deforested or degraded landscapes with low population density (< 10 people/km²) where such forests formerly dominated the landscape. Mosaic restoration integrates trees (scattered across the landscape or in patches) into mixed-use landscapes in which agricultural use and settlements are prominent and into dry landscapes with sparse tree vegetation. This is by far the most widespread opportunity. Trees in these regions can support people by improving water quality, increasing soil fertility, and boosting other ecosystem services. This type of restoration was thought to be most feasible in deforested or degraded landscapes with moderate population density (10–100 people/km²). Remote restoration, finally, is the term used for deforested or degraded areas that are completely unpopulated and located far away from human settlements, such as northern Canada and Siberia. The reduced density of forests in these areas is probably due to fire and pests rather than human interventions, and their remoteness makes them a more costly, lower-priority restoration opportunity. Forest landscape restoration does not call for increasing tree cover beyond what would be ecologically appropriate for a particular location. It should not cause any loss or conversion of natural forests, grasslands, or other ecosystems, nor introduce any alien invasive species (Reytar, 2014).

for existing international commitments (Saint-Laurent, 2015). It was designed to catalyze early action on Reducing Emissions from Deforestation and Forest Degradation (REDD+) under the UNFCCC (to slow, halt and reverse forest cover and carbon loss), as well as action towards achieving CBD Aichi Biodiversity Target 15 (of restoring at least 15 percent of the world's degraded ecosystems by 2020). The Rio+20 Summit in 2012 agreed the global goal of zero net land degradation, in support of the United Nations Convention to Combat Desertification (UNCCD), to which the Bonn Challenge also contributes. The first commitments to the Bonn

Challenge were announced at the Rio+20 Summit and the UNFCCC Conference of the Parties (COP) in Doha, Qatar, in 2012, totalling about 20 million ha. Table 1 identifies the commitments made to the Bonn Challenge.

By indicating at a general level the areas where restoration opportunities were more likely to be found, the map also provided the impetus for deeper research (Maginnis *et al*., 2014). The map has been an effective tool for leveraging political support, but it cannot (and must not) be used as an operational planning tool at the national level (Laestadius *et al*., 2011). The map, in other words, calls for additional analysis at a finer level, "closer to the ground", which has led to the development of the Restoration Opportunities Assessment Methodology (ROAM) (see Box 1).

As a demonstration of further momentum behind the Bonn Challenge target, in September 2014 the UN Climate Summit included the Bonn Challenge in the New York Declaration on Forests and extended it by a minimum of 200 million ha more by 2030 – with the endorsement of over 100 governments, civil society and indigenous organizations, and private enterprises (UN, 2014). The Climate Summit saw the announcement of a further 30 million ha of contributions to the Bonn Challenge, thus bringing the total to more than 50 million ha. The UNFCCC COP in December 2014 saw the formal launch of Initiative 20×20 – a country-led effort to bring 20 million ha of land in Latin America and the Caribbean into restoration by 2020. Initiative 20×20 seeks to change the dynamics of land degradation in this region by using US$365 million of new private investment to restore land. Already, seven Latin American and Caribbean countries and two regional programmes have committed to begin restoring over 20 million ha of degraded land by 2020. This is an area larger than Uruguay (WRI, 2014). Of these 20 million ha, 10.1 have been confirmed as contributions to the Bonn Challenge, bringing the total to 61.5 million ha and putting the halfway mark within reach. Other expressions of interest have also been received; the International Network for Bamboo and Rattan (INBAR) has called upon its 40 members to identify at least 5 million ha, and the regional "Bosques Modelo" programme plans to restore up to 1.6 million ha for its participating landowners and managers (Saint-Laurent, 2015).

TABLE 1. Results since 2011: official commitments announced during the Bonn Challenge Ministerial Roundtable, the Rio+20 Summit, the Doha UNFCCC COP and the UN Climate Summit 2014

Country	Area (million ha)
Brazil/Mata Atlantica Pact	1.1
Colombia	1.0
Costa Rica	1.0
Democratic Republic of the Congo	8.0
El Salvador	1.0
Ethiopia	15.0
Guatemala	3.9
Rwanda	2.0
Uganda	2.5
United States	15.0
Chile, Ecuador, Mexico, Peru and Conservación Patagónica	10.0
Total amount committed so far:	**60.5**

Analysis shows that achieving both the Bonn Challenge and New York Declaration targets, which would restore 350 million ha in total, could have significant environmental, economic and social impacts. Reaching the 350 million ha by the 2030 target would result in an estimated average of 0.6–1.7 Gt CO_2e absorbed per year, reaching 1.6 –3.4 Gt per year in 2030 and totalling 11.8–33.5 Gt over the period 2011–2030 (Verdone *et al*., 2015). This represents a potentially significant contribution to combating climate change. At the low end, 0.6 Gt CO_2e is approximately equal to the annual global increase in emissions from fossil fuel combustion.[1] At the upper end, 1.7 Gt CO_2e is equivalent to the reduction in emissions that would come about if coal-powered stations across the world fully implemented best practices to improve efficiency. It is also of a similar magnitude to Russia's annual greenhouse gas emissions (Verdone *et al*., 2015). Apart from climate change mitigation, restoration is an essential component of any practical plan to feed an additional 3 billion people with sustainable and climate-smart agriculture (Saint-Laurent, 2015). Restoring the productivity of often highly degraded urban watersheds and croplands will also increasingly become a key part of the sustainable cities agenda (Saint-Laurent, 2015).

Whilst political commitments are essential to build momentum for a restoration movement, it is now urgent to translate them into a sustained process on the ground. Ministers from around the world gathered in Bonn, Germany, in March 2015 for the second ministerial meeting aimed at building support for ambitious global forest landscape restoration targets. The meeting was convened by the Governments of Germany and Norway, together with IUCN and WRI. Four major actions were proposed: 1) creation of a finance working group led by the Global Environment Facility (GEF) and Barclays Bank to develop concrete proposals for mobilizing funding and to deepen understanding of what key funding constraints must be addressed; 2) establishment of learning exchanges on key topics, including business models, effective policies and planning, citizen mobilization and capacity building and training; 3) ensuring that countries develop capacity to monitor progress and share lessons learned, including innovative platforms and simple progress indicators; 4) the timely organization of a series of regional gatherings to bring discussions closer to the field, deepen the understanding of constraints and opportunities, and enable neighbouring countries to share their experiences (Sizer *et al*., 2015).

[1] http://edgar.jrc.ec.europa.eu/news_docs/jrc-2014-trends-in-global-co2-emissions-2014-report-93171.pdf

Box 1
The Restoration Opportunities Assessment Methodology (ROAM)

IUCN and WRI created a Restoration Opportunities Assessment Methodology (ROAM) to help stakeholders formulate what might be called the business case for restoration: to determine what restoration activities provide the greatest ecological, social and economic benefits in a particular area of degraded land, to understand the social, legal and institutional context that will best enable restoration, and to formulate strategies for moving forward at the national or subnational level. Governments and non-governmental actors in several countries, including Brazil, Ethiopia, Ghana, Kenya, Mexico and Rwanda, have already begun detailed restoration opportunity assessments (Laestadius *et al*. 2015). ROAM includes a number of components: Restoration Opportunities Mapping, Restoration Economic Valuation, Restoration Carbon Accrual Analysis, a Diagnostic of Key Success Factors and Restoration Finance Assessment. It includes descriptions of the individual tools and components as well as guidance on how they can be combined and sequenced to suit different needs (Maginnis *et al*., 2014).

A host of countries, including Costa Rica, the Niger, the Republic of Korea, Sweden, and the United States of America, have recovered forest landscapes during the past century on a scale that is significant relative to the country's overall size. Analysis of these and other cases suggests that successful restoration exhibits three common themes: 1) A clear motivation exists. Where active restoration was pursued, decision-makers, landowners, and/or citizens were inspired or motivated to restore trees and forests within landscapes; 2) Enabling conditions are in place. Ecological, market, policy, social, and institutional conditions were in place that created a favourable context for forest landscape restoration; 3) Capacity and resources exist for sustained implementation. Capacity and resources were mobilized to implement forest landscape restoration on a sustained basis on the ground.

These insights underpin the *Restoration Diagnostic* – an assessment tool for identifying which key success factors for forest landscape restoration are already in place and which are missing within an area being considered for restoration. By identifying the gaps, decision-makers and land managers can more effectively prioritize policies, incentives, and practices to increase the likelihood that restoration will be a success.

Theme	Feature	Key success factor	Status
Motivate	Benefits	Restoration generates economic benefits	In place
		Restoration generates social benefits	In place
		Restoration generates environmental benefits	In place
	Awareness	Benefits of restoration are publicly communicated	In place
		Opportunities for restoration are identified	In place
	Crisis events	Crisis events are leveraged	In place
	Legal requirements	Law requiring restoration exists	In place
		Law requiring restoration is broadly understood and enforced	Not in place
Enable	Ecological conditions	Soil, water, climate, and fire conditions are suitable for restoration	Partially in place
		Plants and animals that can impede restoration are absent	Not in place
		Native seeds, seedlings, or source populations are readily available	Partially in place
	Market conditions	Competing demands (e.g. food, fuel) for degraded forestlands are declining	Not in place
		Value chains for products from restored areas exist	In place
	Policy conditions	Land and natural resource tenure are secure	Not in place
		Policies affecting restoration are aligned and streamlined	Partially in place
		Restrictions on clearing remaining natural forests exist	In place
		Forest clearing restrictions are enforced	Partially in place
	Social conditions	Local people are empowered to make decisions about restoration	Partially in place
		Local people are able to benefit from restoration	Partially in place
	Institutional conditions	Roles and responsibilities for restoration are clearly defined	Partially in place
		Effective institutional coordination is in place	Partially in place
Implement	Leadership	National and/or local restoration champions exist	Not in place
		Sustained political commitment is in place	Partially in place
	Knowledge	Restoration know-how relevant to candidate landscapes exists	Partially in place
		Restoration know-how is transferred via peers or extension services	Partially in place
	Technical design	Restoration design is technically grounded and climate-resilient	Partially in place
		Restoration limits "leakage"	Partially in place
	Finance and incentives	Positive incentives and funds for restoration outweigh negative incentives	Partially in place
		Incentives and funds are readily accessible	Partially in place
	Feedback	An effective performance monitoring and evaluation system is in place	Partially in place
		Early successes are communicated	In place

Key
- In place
- Partially in place
- Not in place

Source: Hanson *et al*., 2015.

© TONY RINAUDO, WORLD VISION AUSTRALIA

© TONY RINAUDO, WORLD VISION AUSTRALIA

Landscape in Ethiopia before and after restoration

CONCLUSIONS

The concept of FLR evolved out of forestry in the late 1990s, and the GPFLR was launched in 2003, but it was not until the first Bonn Challenge Ministerial Roundtable in 2011 that the restoration movement started to take off, posing the challenge of how to transform political commitment into sustained action on the ground.

This welcome shift into a new phase poses new issues for the GPFLR. The movement cannot be taken to scale without the support and engagement of a broad range of stakeholders, notably those associated with agriculture. Governments are also extremely important as only they can mobilize the necessary level of public budget and incentives for the private sector in order to promote investment in restoration. The GPFLR must therefore define and communicate FLR in a way that is understandable and attractive to all stakeholders in the broader landscape. It must provide a portfolio of restoration techniques that includes methods that are ecologically robust and require little financial investment. It must develop mechanisms for capturing and sharing the experiences of countries and other actors as they embark on restoration on a large scale, providing a foundation for learning and adaptive management. It must ensure that appropriate methods for monitoring are available and applied.

The GPFLR needs to leverage new partnerships and catalyze the use of new technologies to build the landscapes of the future, landscapes that need to be resilient and capable of adapting to the effects of climate change. We have to start building today the landscapes we will need tomorrow. ◆

References

CBD. 2010. *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its tenth meeting*. UNEP/CBD/COP/DEC/X/2. 29 October 2010 (available at https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-02-en.pdf). Accessed 06/17/2015.

Cossalter, C. & Pye-Smith, C. 2003. *Fast-wood forestry: myths and realities*. Bogor, Indonesia, CIFOR.

FAO. 2000. Trees outside forests: an essential tool for desertification control in the Sahel. *Unasylva*, 200 (51): 18–24 (available at http://www.fao.org/docrep/x3989e/x3989e00.htm).

GPFLR. 2013. The Bonn Challenge (available at http://www.forestlandscaperestoration.org/topic/bonn-challenge).

Hanson, C., Buckingham, K., Dewitt, S. & Laestadius, L. 2015. *Restoration diagnostic*. Washington, DC, World Resources Institute.

IISD. 2002. Summary of the International Expert Meeting on Forest Landscape Restoration 27–28 February 2002. *Sustainable Developments*. Vol. 71, No. 1 (2 March 2002) (available at http://www.iisd.ca/crs/sdcfr/sdvol71num1.html). Accessed 3 March 2015.

IISD. 2005. A brief history of the UNFF and the Global Partnership on FLR. *Petrópolis Restoration Workshop Bulletin*, Vol. 107:1 (11 April 2005). Accessed 3 March 2015.

ITTO. 2002. *ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests*. ITTO Policy Development Series No. 13. Yokohama, Japan, ITTO, in collaboration with IUCN, WWF, CIFOR, FAO.

IUCN. 2002. *Building Assets for People and Nature: International Expert Meeting on Forest Landscape Restoration* [overview] (available at http://cmsdata.iucn.org/downloads/international_expert_meeting_on_forest_landscape_restoration.pdf).

IUCN & WWF. 2000. *Forests Reborn: A Workshop on Forest Restoration* [overview] (available at https://cmsdata.iucn.org/downloads/flr_segovia.pdf).

IUCN & WWF. 2002. *International Expert Meeting on Forest Landscape Restoration* [overview] (available at http://cmsdata.iucn.org/downloads/international_expert_meeting_on_forest_landscape_restoration.pdf).

Janzen, D.H. 2000. Costa Rica's Area de Conservación Guanacaste: A long march to survival through non-damaging biodevelopment. *Biodiversity*, 1(2): 7–20.

Laestadius, L., Maginnis, S., Minnemayer, S., Patapov, P., Saint-Laurent, C. & Sizer, N. 2011. Mapping opportunities for forest landscape restoration. *Unasylva*, 238(62): 47–48 (available at www.fao.org/docrep/015/i2560e/i2560e08.pdf).

Laestadius, L., Reytar, K., Maginnis, S. & Saint-Laurent, C. 2015. Demystifying the world's forest landscape restoration opportunities. *World Resources Institute blog* (available at http://www.wri.org/blog/2015/03/demystifying-worlds-forest-landscape-restoration-opportunities). Accessed 3 August 2015.

Lamb, D. & Gilmour, D. 2003. *Rehabilitation and restoration of degraded forests*. Gland, Switzerland, and Cambridge, United Kingdom, IUCN.

Maginnis, S. & Jackson, W. 2002. *Restoring forest landscapes: Forest landscape restoration aims to re-establish ecological integrity and enhance human well-being in degraded forest landscapes* [concept paper]. IUCN (available at http://cmsdata.iucn.org/downloads/restoring_forest_landscapes.pdf).

Maginnis, S., Jackson, W.J. & Dudley, N. 2004. Conservation landscapes: Whose landscapes? Whose trade-offs? In T.O. McShane & M.P. Wells, eds. *Getting biodiversity projects to work: more effective conservation and development*. New York, Columbia University Press.

Maginnis, S., Rietbergen-McCracken, J. & Jackson, W. 2005. *Restoring forest landscapes: an introduction to the art and science of forest landscape restoration*. Technical Series No. 23. Yokohama, ITTO (available at http://www.itto.or.jp/live/Live_Server/1064/ts23e.pdf).

Maginnis, S., Laestadius, L., Verdone, M., DeWitt, S., Saint-Laurent, C., Rietbergen-McCracken, J. & Shaw, D.M.P. 2014. *A guide to the Restoration Opportunities Assessment Methodology (ROAM): Road-Test Edition*. Geneva, Switzerland, IUCN (available at https://www.iucn.org/about/work/programmes/forest/fp_our_work/fp_our_work_thematic/fp_our_work_flr/approach_to_forest_landscape_restoration/restoration_opportunities_assessment_methodology/). Accessed 3 March 2015.

Mansourian, S., Vallauri, D. & Dudley, N. 2005. Forest restoration in landscapes: beyond planting trees. New York, Springer Science and Business Media, WWF.

Minnemeyer, S., Laestadius, L., Sizer, N., Saint-Laurent, C. & Potapov, P. 2011. A world of opportunity [brochure]. The Global Partnership on Forest Landscape Restoration, World Resources Institute, South Dakota State University and IUCN (available at http://pdf.wri.org/world_of_opportunity_brochure_2011-09.pdf).

Reytar, K. 2014. 7 Unexpected places for forest landscape restoration. *World Resources Institute blog* (available at http://www.wri.org/blog/2014/05/7-unexpected-places-forest-landscape-restoration). Accessed 3 March 2015.

Röttgen, N. & Khosla, A. 2011. *Bonn Challenge on Forests, Climate Change and Biodiversity Ministerial Roundtable* [summary]. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (available at http://www.bmub.bund.de/fileadmin/bmu-import/files/pdfs/allgemein/application/pdf/bonn_challenge_summary.pdf).

Saint-Laurent, C. 2005. Optimizing synergies on forest landscape restoration between the Rio Conventions and the UN Forum on Forests to deliver good value for implementers. *Review of European Community & International Environmental Law*, 14(1): 39–49.

Saint-Laurent, C. 2015. *Forest Landscape Restoration and the Bonn Challenge* [backgrounder]. IUCN.

Sayer, J., Kapos, V., Mansourian, S. & Maginnis, S. 2003. *Forest landscape restoration: the role of forest restoration in achieving multifunctional landscapes*. Paper presented at the XII World Forestry Congress, 2003, Quebec City, Canada (available at http://www.fao.org/docrep/ARTICLE/WFC/XII/0670-B3.HTM).

Sizer, N., DeWitt, S. & Messinger, J. 2015. Bonn Challenge 2.0: Forest and landscape restoration emerges as a key climate solution. *World Resources Institute blog* (available at http://www.wri.org/blog/2015/04/bonn-challenge-20-forest-and-landscape-restoration-emerges-key-climate-solution-1).

UN. 2014. New York Declaration on Forests Action Statements and Action Plans. United Nations Climate Summit 2014. Website (available at http://www.un.org/climatechange/summit/action-areas/#forests).

UNFF. 2005. *Report of the fifth session (14 May 2004 and 16 to 27 May 2005)*. E/2005/42. E/CN.18/2005/18. Economic and Social Council Official Records, 2005. Supplement No. 22 (available at http://daccess-dds-ny.un.org/doc/UNDOC/GEN/N05/396/66/PDF/N0539666.pdf?OpenElement).

Van Oosten, C. 2009. *Global Partnership on Forest Landscape Restoration: Towards a global learning network of sites*. Wageningen, Netherlands, Wageningen University.

Verdone, M., Olsen, N., Wylie, P., Saint Laurent, C. & Maginnis, M. 2015. *Making the case for forest landscape restoration*. White paper, initial working draft for future discussion. Post-Bonn Challenge 2.0 Ministerial Event, 20–21 March 2015, IUCN.

Wenger, R., Sommer, R. & Wymann von Dach, S. 2005. Forest Landscape Restoration (FLR). *InfoResources Focus*, 2(5).

WRI. 2014. *Initiative 20 x 20*. Washington, DC, World Resources Institute (available at http://www.wri.org/our-work/project/initiative-20×20/about-initiative-20×20#project-tabs). Accessed 3 March 2015. ◆

Ecosystem restoration, protected areas and biodiversity conservation

L. Janishevski, C. Santamaria, S.B. Gidda, H.D. Cooper and P.H.S. Brancalion

© PEDRO BRANCALION

Above: Blooming **Handroanthus impetiginosus** *tree (Bignoniaceae) in the Brazilian Atlantic Forest*

Ecosystem restoration on a landscape scale strengthens biodiversity conservation in protected areas.

Lisa Janishevski is Programme Assistant in the Science, Assessment and Monitoring Division of the Convention on Biological Diversity (CBD) Secretariat, Montreal, Canada.
Catalina Santamaria is Forest Biodiversity Programme Officer in the Science, Assessment and Monitoring Division of the CBD Secretariat, Montreal, Canada.
Sarat Babu Gidda is Programme Officer for in-situ and ex-situ conservation in the Science, Assessment and Monitoring Division of the CBD Secretariat, Montreal, Canada.
H. David Cooper is Principal Officer in the Science, Assessment and Monitoring Division of the CBD Secretariat, Montreal, Canada.
Pedro H. S. Brancalion is Professor in the Department of Forest Sciences, Luiz de Queiroz College of Agriculture, University of São Paulo, Piracicaba-SP, Brazil.

This article focuses on the opportunities for ecosystem restoration to contribute to biodiversity conservation within and outside protected areas (as discussed, for example, in Brancalion *et al*., 2013a).

Ecosystem restoration on a landscape scale, alongside the sustainable management of other land-use types including agriculture, pasturelands, forestry, and the expansion and consolidation of protected areas, is increasingly recognized as a necessary part of a package of activities for biodiversity conservation, enhanced ecosystem services and sustainable development (SCBD, 2014; Aronson and Alexander, 2013; Menz *et al*., 2013; Rey Benayas *et al*., 2009; Bullock *et al*., 2011).

The Convention on Biological Diversity (CBD) states that each Party shall, as far as possible, "rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, including through the development and implementation of plans or other management strategies".[1] To further the implementation of this provision and Aichi Biodiversity Targets 14 and 15 (Box 1), the Conference of the Parties (COP) to the Convention adopted a comprehensive decision on ecosystem

[1] Article 8(f) of the Convention: http://www.cbd.int/convention/text/.

Box 1
Strategic Plan for Biodiversity 2011–2020

The Strategic Plan for Biodiversity 2011–2020 was adopted by the CBD COP at its tenth meeting in Nagoya, Japan, in October 2010. It is supported by the other biodiversity-related conventions and by the United Nations. It thus provides an internationally agreed framework for action on biodiversity with a vision that foresees that:

> By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people.

The Plan includes twenty Aichi Biodiversity Targets including Target 15:

> By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 percent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

Actions to achieve the Aichi Targets should be undertaken in a coherent and coordinated manner. In particular, efforts to achieve Target 15 on ecosystem restoration should be closely linked to those aimed at halving deforestation and reducing the loss and degradation of other natural habitats (Target 5), promoting sustainable agriculture and forestry (Target 7) and protecting at least 17 percent of terrestrial areas through a system of protected areas integrated into the wider landscape (Target 11). Achieving these targets will together help to protect threatened species (Target 12), genetic diversity (Target 13) and ecosystem services (Target 14). The full text of the Targets is available at: http://www.cbd.int/sp/targets/default.shtml.

At the national level, implementation of the Strategic Plan for Biodiversity is promoted through national biodiversity strategies and action plans. Attaining the Aichi Biodiversity Targets will in most cases require the implementation of a package of actions, typically including legal or policy frameworks, socioeconomic incentives aligned to such frameworks, public and stakeholder engagement, monitoring and enforcement. Coherence of policies across sectors and the corresponding government ministries is also necessary.

Meeting the Aichi Biodiversity Targets would contribute significantly to broader global priorities addressed by the post-2015 development agenda, namely: reducing hunger and poverty; improving human health; ensuring a sustainable supply of energy, food and clean water; contributing to climate change mitigation and adaptation; combating desertification and land degradation; and reducing vulnerability to disasters (SCBD, 2014).

restoration in 2012,[2] backed up by the Hyderabad Call for a Concerted Effort on Ecosystem Restoration.[3] To provide support to developing-country Parties on implementing these decisions and achieving these targets, the Forest Ecosystem Restoration Initiative, supported by the Government of the Republic of Korea through the Korea Forest Service (KFS), was launched at CBD COP 12 in October 2014.

These aspirations are reflected in the Bonn Challenge[4] to restore 150 million ha of degraded land by 2020. On the margins of the UN Climate Summit in September 2014[5] a number of governments, as well as civil society and private-sector organizations, signed the New York Declaration on Forests, extending the goal by an additional 200 million ha to be restored by 2030.[6]

[2] Decision XI/16: http://www.cbd.int/decision/cop/default.shtml?id=13177.

[3] The Hyderabad Call for a Concerted Effort on Ecosystem Restoration was made by the Governments of India, the Republic of Korea and South Africa (as then COP Presidents of the CBD, UNCCD and UNFCCC) and heads of a number of international organizations: http://www.cbd.int/doc/restoration/Hyderabad-call-restoration-en.pdf.

[4] http://www.forestlandscaperestoration.org/topic/bonn-challenge; http://www.forestlandscape restoration.org/sites/default/files/topic/the_bonn_challenge.pdf.

[5] See http://www.un.org/climatechange/summit/.

[6] See Panel-5 discussions at http://www.un-redd.org/Portals/15/documents/Report%20on%20the%20Forests%20Pavilion%2023%20September%202014%20v2.pdf.

© PEDRO BRANCALION

Community-managed agroforests made up of banana, manioc and juçara *(an endangered native palm, the fruits of which are exploited for pulp production), at the borders of the Serra do Mar State Park in the Atlantic Forest of São Paulo, Brazil. Such agroforests supply food and provide income to traditional populations living around the protected area, thus avoiding illegal harvesting of wood and non-wood forest products in the reserve. In this context, forest restoration and rehabilitation are useful to reduce human-mediated disturbances in protected areas and to improve the connectivity of landscapes that embrace protected areas*

Efforts to restore ecosystems also contribute to other internationally agreed goals, including ecosystem-based adaptation and climate change mitigation under the United Nations Framework Convention on Climate Change (UNFCCC),[7] land-degradation neutrality under the United Nations Convention to Combat Desertification (UNCCD),[8] the wise use of wetlands under the Ramsar Convention on Wetlands,[9] and the four Global Objectives on Forests of the United Nations Forum on Forests.[10] Ecosystem restoration is also recognized in the Sustainable Development Goals.[11]

Ecosystem restoration at the landscape scale reflects a paradigm shift in conservation science, putting spatial pattern and scale at the centre of conservation strategies, where, instead of focusing exclusively on reserves, conservation efforts maximize the value of rural landscapes for biodiversity persistence, preventing extinctions, and for the provision of ecosystem services (Chazdon *et al*., 2009). This shift was also reflected in the discussions and outcomes of the 5th International Union for Conservation of Nature (IUCN) World Parks Congress in 2003 under the overarching theme of "Benefits beyond boundaries", as well as in the goals and activities of the Programme of Work on Protected Areas adopted under the CBD in 2004.

WHY LANDSCAPE RESTORATION IS NEEDED FOR BIODIVERSITY CONSERVATION

Significant efforts have been made in recent years to develop protected area networks within the framework of the CBD's Programme of Work on Protected Areas. The world is now on track to protect 17 percent of terrestrial areas by 2020, in line with Aichi Biodiversity Target 11 (SCBD, 2014). However, achieving a well-managed and representative network will require greater efforts. Moreover, extrapolations of current trends indicate that pressures on biodiversity will continue to increase and the status of biodiversity will continue to decline. Analysis of the major primary sectors indicates that drivers linked to agriculture account for some two-thirds of the projected loss of terrestrial biodiversity (SCBD, 2014).

Many protected areas are embedded within human-modified landscapes (Melo *et al*., 2013a), where agriculture

7 http://unfccc.int/2860.php.

8 http://www.unccd.int/.

9 www.ramsar.org.

10 www.un.org/esa/forests.

11 For details, see https://sustainabledevelopment.un.org/sdgsproposal, and in particular for restoration targets 6.6 (water-related ecosystems), 14.2 (marine and coastal ecosystems), 15.1 (terrestrial and inland freshwater ecosystems), 15.2 (degraded forests), and 15.3 (degraded land and soil).

and urbanization have determined landscape structure and may represent major disturbances to natural ecosystems. Habitat loss and fragmentation is a major threat to biodiversity conservation in this context. Recent studies have shown that below certain percentages of habitat cover, human-modified landscapes show an abrupt decline in biodiversity as a result of the lack of connectivity among remaining habitat patches (Rappaport *et al*., 2015). Thus, when embedded in landscapes with very low habitat cover – predominant in many regions – protected areas without connectivity to the surrounding landscape have a limited potential to avoid further species extinctions. The critical habitat cover for biodiversity conservation varies according to ecosystem type, landscape matrix, and focus organisms (Fahrig, 2001) and, although theoretical research has indicated 20–30 percent habitat cover as a relevant threshold, further empirical testing is required (Fahrig, 2003). For example, forecasting by Ferro *et al*. (2014) found that most protected areas in the Brazilian Atlantic Forest would become climatically unsuitable for maintaining the diversity of tiger moths (*Arctiinae*) by 2080. Climate change will likely impose additional challenges for biodiversity confined to reserves. Some species may be forced to shift their geographical ranges in order to find climate refuges. For example, not only are marsupial species in Brazil forecast to shift ranges towards the southeast of the country, culminating in high species richness in that area, but most species will also experience significant range contraction and loss of climatically suitable areas within their geographic range (Loyola *et al*., 2012). Thus, protected areas increasingly need to be functionally connected to other habitat patches in the landscape to allow species movement to more favourable sites. In a changing world, we have to improve the dynamic interaction between protected areas and the other components of the inter-habitat mosaic (Hobbs *et al*., 2014). In other words, we have to manage the system (i.e. the landscape), and not only its parts (i.e. protected areas and other patches of natural habitat).

Thus, to sustain desirable levels of connectivity and foster biodiversity conservation in protected areas, the maintenance and restoration of smaller remnants in the landscape need to be taken into account, and in highly fragmented landscapes may be the only option available. In such conditions, landscape restoration is vital to support biodiversity conservation over time, complemented by improved coverage of isolated semi-natural habitats in landscape management plans. In human-modified landscapes, the conservation

Multiple landscape restoration interventions in the Brazilian Atlantic Forest: silvopastoral systems, living fences, natural regeneration in marginal agricultural areas and restoration plantations on mountaintops and steep slopes

© PEDRO BRANCALION

© PEDRO BRANCALION

A large part of the Vassununga State Park in the Brazilian Atlantic Forest burned in a fire that began at the borders of the road that crosses the park. Climate change tends to intensify and increase the frequency of forest fires in tropical regions, representing an important risk for protected areas. If protected areas are connected to other remnants in the landscape through ecological corridors established by restoration interventions, fauna can better escape from areas submitted to human-mediated disturbances, and the recolonization process of destroyed or disturbed parts of protected areas can be facilitated

focus thus needs to move beyond the protection of existing remnants, while addressing landscape constraints and interactions to support the persistence of biodiversity (Gardner *et al*., 2009).

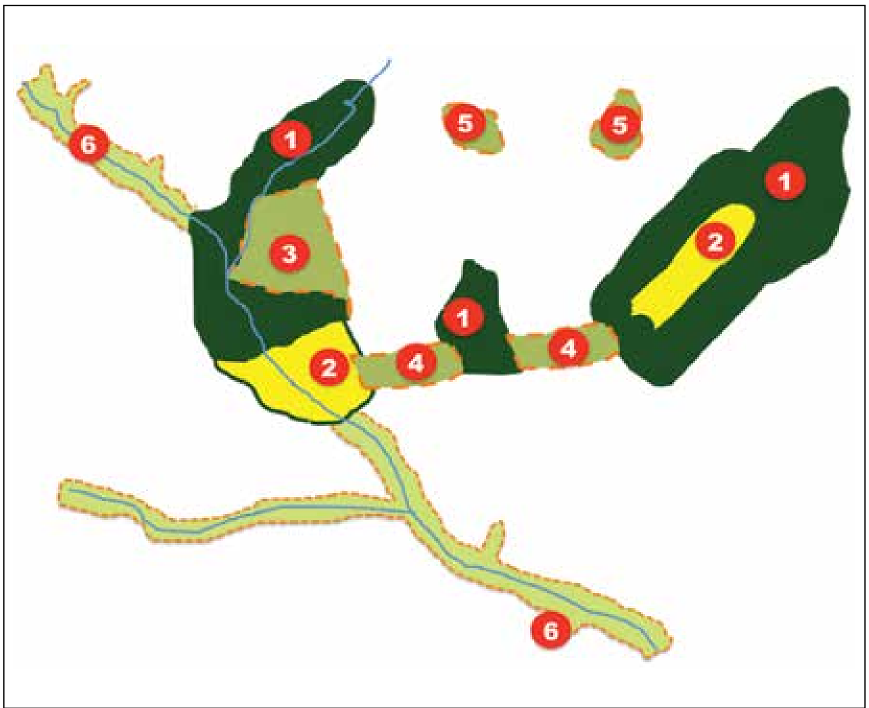
Such an approach is consistent with Aichi Biodiversity Target 11, which calls for "effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures [...] integrated into the wider landscape and seascape". The CBD Programme of Work on Protected Areas elaborates on the concept of integrating protected areas into wider land- and seascapes,[12] and Ervin *et al*. (2010) have produced a relevant guide in the CBD Technical Series.

In identifying possible areas for restoration, consideration should be given to improving the extent, quality and connectivity of high-biodiversity areas, including areas that are home to threatened or endangered species, and those that deliver important ecosystem services (Tambosi *et al*., 2014). Restoration must be informed by a vision of enhancing native ecosystem functions and avoiding further reduction or conversion of natural habitat cover, or loss in other natural ecosystems (Latawiec *et al*., 2015). Vulnerable areas with the potential to contribute to a matrix of conservation and sustainable use can be accorded appropriate levels of protection and targeted for restoration as needed. Areas can be protected against human-mediated disturbances and reconnected to other habitat remnants in the landscape. In addition, the hospitability of the agricultural landscape "matrix" (within which protected areas and other areas of native vegetation are embedded) to species that may move among these natural patches can be improved through various forms of landscape restoration. This may include forest restoration and interventions to increase tree cover in agricultural landscapes, such as agroforestry, "living fences", and the establishment of appropriate tree plantations.

Brancalion *et al*. (2013b) proposed an approach in which forest and landscape restoration (FLR) supports biodiversity conservation in protected areas embedded within human-dominated landscapes. The approach is based on the premise that, in many tropical areas, forest remnants large enough to receive public investments for strict protection have become scarce, while small- and medium-sized, privately owned fragments may play a significant role in conserving stressed biodiversity. Historically, the conservation role of such small remnants has been underestimated by conservationists because these areas may harbour far lower levels of biodiversity than do the larger protected or otherwise conserved remnants. This reflects a limited view of biodiversity conservation, as small remnants can serve as ecological corridors or stepping stones. The approach, which the authors call "restoration reserves", uses the following multi-scale decision-making scheme:

1. definition of priority areas for increasing landscape connectivity through ecological restoration at the regional scale;
2. selection of a given landscape where ecological restoration shows high

[12] Goal 1.2 of the Programme of Work on Protected Areas: http://www.cbd.int/protected/.



1
Priority areas for restoration at the landscape level from a biodiversity conservation perspective.
Dark green areas (1) depict areas of native vegetation (e.g. remnants of old-growth forest). These areas are a priority for conservation and may already be included in protected areas. The areas shown in yellow (2) and bounded by dark green lines represent degraded native vegetation. Ecological restoration of these areas would improve the integrity of the associated high-conservation areas. Areas shown in mid-green, bounded by broken brown lines (3–6), depict priority areas for restoration from agriculture or rangeland areas, with the following rationales: improving the integrity of existing areas of native vegetation (3) by reducing edge effects and increasing size; providing ecological corridors (4) or stepping stones to improve connectivity (5); and protecting riparian areas from erosion (6). Finally, the hospitability of the agricultural landscape matrix may be improved through agroforestry.

potential for increasing landscape connectivity, using this to define the boundaries of the area within which landscape-scale restoration is to be promoted; and

3. implementation of ecological restoration activities aimed at increasing biodiversity conservation and landscape connectivity within these areas, such as
   - protection of existing forest remnants;
   - restoration of degraded areas of native vegetation;
   - increasing of the size and/or improvements to the shape of remnants to reduce edge effects; and
   - restoration of some lands that have been converted to agriculture, especially degraded or low-productivity lands, to establish ecological corridors and stepping stones or to enlarge existing corridors (Figure 1).

Ecosystem restoration is not a substitute for conservation, nor should it be used to justify degradation or unsustainable use. Old-growth forests and other areas of near-pristine native vegetation are the main repositories of biodiversity in human-modified landscapes, and are a necessary source of biodiversity for colonizing restoration sites within agricultural landscapes.

Indeed, although restoration has been effective in increasing biodiversity levels in degraded sites, it has not been enough to achieve the reference values of conserved ecosystems (Rey Benayas *et al*., 2009). Consequently, a main premise of landscape restoration should be to halt habitat loss, especially of those ecosystems that provide essential ecosystem services and have a higher potential to retain their biological composition and functions. Although some tropical landscapes have experienced a forest transition where forest gains have surpassed deforestation and thus brought about a net gain in forest cover, old-growth forest remnants have nevertheless often been replaced by crop fields and pasturelands in areas favourable for agricultural production (Ferraz *et al*., 2014). This significantly affects the viability of species in existing and future restoration sites, as well as pollination, pest control, and other ecosystem services mediated by biodiversity in agroecosystems. Restoration outcomes are also affected by landscape structure, land-use history and disturbance regime, which increase the risk of using restoration to offset biodiversity losses in natural ecosystems (Maron *et al*., 2012).

Diversity between and within species is important for effective ecosystem restoration, not only to promote high conservation value in the restored ecosystems but also to ensure the success of the restoration process itself (Thomas *et al*., 2014; Bozzano *et al*., 2014). Restoration activities should also be undertaken in a manner consistent with the ecosystem approach developed under the CBD.[13] In particular, forest landscape restoration should only be undertaken where ecologically appropriate. Although afforestation and reforestation are part of forest-restoration strategies, such measures should be critically assessed in natural ecosystems. Working across the whole landscape with

[13] Ecosystem approach operational guidance: https://www.cbd.int/ecosystem/operational.shtml and Principles: http://www.cbd.int/ecosystem/principles.shtml.

a mosaic of land uses requires assessments of the ecological conditions, sociocultural dynamics and other enabling factors in order to assess trade-offs and adjust land-use plans accordingly. Each country needs to determine what is ecologically appropriate and establish its baseline maps, with monitoring systems in place to track and guide progress in the various ecosystems. Countries will need to assess opportunities for restoring deforested and degraded landscapes and factor in the rehabilitation of degraded agricultural lands to improve productivity in mosaic landscapes, without causing loss or conversion of native forests, grasslands or other natural ecosystems (Veldman *et al*., 2015).

THE CASE OF THE BRAZILIAN ATLANTIC FOREST

Despite growing international recognition of the importance of ecological restoration, large-scale FLR programmes are only at their beginning, which limits our understanding of the real needs and success factors of such activities for complementing biodiversity conservation in protected areas. To improve understanding, we selected the restoration of the Brazilian Atlantic Forest as a case study. The study provides local lessons in ecosystem conservation and restoration with regard to protected-area management, and is a concrete example of a contribution to globally agreed goals under the Strategic Plan for Biodiversity 2011–2020 and the emerging Sustainable Development Goals. It was chosen on the basis of the biological importance of the biome concerned, which is among the top five Global Biodiversity Hotspots (Laurance, 2009), and the existence of a large-scale, successful programme for FLR: the Atlantic Forest Restoration Pact (Melo *et al*., 2013b).

Only 1.05 percent of the original extent of the Brazilian Atlantic Forest is protected in reserves, which are mostly embedded in highly fragmented landscapes (Ribeiro *et al*., 2009). Since less than 12 percent of the original Atlantic Forest cover (1.2 million km^2) remains today, these

© PEDRO BRANCALION

Protection of a water spring and of a riparian buffer by forest restoration interventions in a private landholding in the Brazilian Atlantic Forest. Although protected areas may be more successful in conserving terrestrial ecosystems, the conservation of freshwater systems relies on management of the whole watershed, and can only be achieved if complementary interventions are made at the watershed scale

protected areas are frequently isolated from neighbouring forest remnants and, considering the small size of the reserves, are often part of landscapes below the habitat-cover threshold required to avoid an abrupt loss of biodiversity. For instance, Banks-Leite *et al*. (2014) observed in this biome an abrupt decline in the community integrity of vertebrates when habitat cover fell to approximately 30 percent. Consequently, maintaining existing protected areas is not enough, in this case, for the long-term persistence of biodiversity. Nor is creating new, formally recognized protected areas on a significant scale a feasible solution, since forest remnants large enough to receive public investments for strict protection have become scarce. However, conserving small- and medium-sized, privately owned fragments, while restoring small areas around protected areas, has been shown to improve the connectivity of landscapes (Brancalion *et al.,* 2013b). In addition, improving tree cover in agricultural landscapes, for example through agroforestry and commercial tree plantations, may also lead to increased landscape hospitability to some endangered species. Further, in highly fragmented landscapes, protecting small remnants and restoring others may be the only option available to reach an adequate level of representativity: this is the case in the protected area network of the Atlantic Forest, where six of its seven biogeographical regions are poorly protected. In such conditions, FLR is even more crucial to support biodiversity conservation over time.

To address this need, a coalition of non-governmental organizations (NGOs), private companies, governments, and academia launched in 2009 the Atlantic Forest Restoration Pact, which currently consists of more than 300 institutions working together to restore 15 million ha of forests by 2050, including a pledge of 1 million ha within the framework of the Bonn Challenge (Melo *et al*., 2013b). If this restoration target is met, the Atlantic Forest would reach 30 percent of forest cover, achieving the estimated minimum threshold for biodiversity persistence, in association with the maintenance and improvement of the protected areas network.

The Pact has developed methodologies for identifying priority areas for restoration that take into account the factors discussed in the previous section (see also Figure 1) with a view to optimizing the contribution to biodiversity conservation without neglecting socioeconomic factors. This view incorporates a well-developed framework for land-use planning, in order to create space for large-scale restoration in agricultural areas and avoid displacing agricultural activities that may cause deforestation elsewhere (Latawiec *et al*., 2015). To achieve its goal, the Pact developed a thematic map of potential areas for restoration, in which nearly 7 million ha of less productive pasturelands (slope >15°) – with a low opportunity cost (less than US$50/ha/year) due to their low productivity and returns to farmers – were targeted for restoration (Pinto *et al*., 2014). The Pact proposes that the implementation of restoration models designed to produce timber and non-wood forest products, as well as to receive payments for ecosystem services, can be profitable and overcome the opportunity costs of less productive pasturelands (Brancalion *et al*., 2012). Maps of priority regions for increasing landscape connectivity have also been produced (Tambosi *et al*., 2014), which may optimize restoration efforts, especially in the regions more recently affected by deforestation. In addition, to increase the cost-effectiveness of restoration through spatial planning, the Pact also looks at the quality of restoration interventions. A reference book summarizing most of the technical and scientific information available on forest restoration in the Atlantic Forest provides scientific guidance to practitioners on environmental diagnosis and planning, restoration methods and operational interventions, seed and seedling production, including genetic issues, and monitoring (Rodrigues *et al*., 2009). More recently, a monitoring protocol was launched to assess the ecological, socioeconomic and management effectiveness of restoration projects and programmes developed by Pact members, and to identify the key obstacles to successful restoration and provide collective solutions (Pinto *et al*., 2014).

The Atlantic Forest Restoration Pact has been integrated not only into global initiatives such as the Bonn Challenge, focusing on large-scale restoration, but also into new laws and policies supporting forest restoration in Brazil. The consequent development of innovative models to transform restoration into an economically and socioecologically viable land-use option thus opens promising perspectives.

CONCLUSIONS

Ecosystem restoration at the landscape level is an essential part of efforts to protect biodiversity and contribute to sustainable development. To be successful in this regard, ecosystem restoration must:

- help to protect the integrity of existing areas of native vegetation, including protected areas, by increasing the size of such areas and reducing edge effects;
- improve connectivity in the landscape, for example by providing ecological corridors or "stepping stones" between existing areas of native vegetation, including protected areas;
- make use of a wide diversity of species in restored areas, taking into account genetic diversity;
- complement efforts to reduce degradation and habitat loss, thereby protecting old-growth remnants and other near-pristine habitats; and
- be implemented in an ecologically appropriate manner, avoiding, for example, afforestation of non-forest natural ecosystems.

Efforts are needed at the landscape level to manage the system rather than just its individual components. This includes not only manipulating its biophysical components, but involving the socioeconomic drivers of both habitat degradation and loss and ecosystem restoration. A key step towards the implementation of effective ecosystem and landscape restoration programmes is to develop governance mechanisms that enable restoration advocates to provide better conditions and incentives for restoration activities, while creating barriers to stop degradation. But overcoming socioeconomic thresholds can be even more challenging than tackling biophysical factors.

Concerted actions for ecological restoration in forest and other landscapes, together with biodiversity conservation in protected areas and a range of complementary interventions to promote sustainable agricultural, rangeland and forest production, will help meet the needs of today and ensure sustainable development for future generations. ◆

References

Aronson, J. & Alexander, S. 2013. Ecosystem restoration is now a global priority: time to roll up our sleeves. *Restoration Ecology*, 21(3): 293–296.

Banks-Leite, C., Pardini, R., Tambosi, L.R., Pearse, W.D., Bueno, A.A., Bruscagin, R.T., Condez, T.H., Dixo, M., Igari, A.T., Martensen, A.C. & Metzger, J.P. 2014. Using ecological thresholds to evaluate the costs and benefits of set-asides in a biodiversity hotspot. *Science*, 345(6200): 1041–1045.

Bozzano, M., Jalonen, R., Thomas, E., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P. & Loo, J., eds. 2014. Genetic considerations in ecosystem restoration using native tree species. *In* Bozzano, M. et al. (eds.), *Genetic considerations in ecosystem restoration using native tree species*. State of the World's Forest Genetic Resources Thematic Study. Rome, FAO and Bioversity International (available at http://www.fao.org/3/a-i3938e.pdf).

Brancalion, P.H.S., Melo, F.P.L., Tabarelli, M. & Rodrigues, R.R. 2013a. Biodiversity persistence in highly human modified tropical landscapes depends on ecological restoration. *Tropical Conservation Science*, 6(6):705–710.

Brancalion, P.H.S., Melo, F.P.L., Tabarelli, M. & Rodrigues, R.R. 2013b. Restoration reserves as biodiversity safeguards in human-modified landscapes. *Natureza & Conservação*, 11(2): 186–190.

Brancalion, P.H.S., Viani, R.A.G., Strassburg, B.B.N. & Rodrigues, R.R. 2012. Finding the money for tropical forest restoration. *Unasylva*, 63(239): 25–34.

Bullock, J.M., Aronson, J., Newton, A.C., Pywell, R.F. & Rey-Benayas, J.M. 2011. Restoration of ecosystem services and biodiversity. *Trends in Ecology and Evolution*, 26: 541–549.

Chazdon, R.L., Harvey, C.A., Komar, O., Griffith, D.M., Ferguson, B.G., Martínez-Ramos, M., Morales, H., Nigh, R., Soto Pinto, L., van Breugel, M. & Philpott, S.M. 2009. Beyond reserves: a research agenda for conserving biodiversity in human modified tropical landscapes. *Biotropica*, 41(2): 142–153.

Ervin, J., Mulongoy, K.J., Lawrence, K., Game, E., Sheppard, D., Bridgewater, P., Bennett, G., Gidda, S.B. & Bos, P. 2010. Making protected areas relevant: a guide to integrating protected areas into wider landscapes, seascapes and sectoral plans and strategies. CBD Technical Series No. 44. Montreal, Canada, Convention on Biological Diversity.

Fahrig, L. 2001. How much habitat is enough? *Biological Conservation*, 100: 65–74.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution and Systematics*, 34: 487–515.

Ferraz, S., Ferraz, K.N.P.M.B., Cassiano, C.C., Brancalion, P.H.S., Luz, D.T.A., Azevedo, T.N., Tambosi, L.R. & Metzger, J.P. 2014. How good are tropical forest patches for ecosystem services provisioning? *Landscape Ecology*, 29(2): 187–200.

Ferro, V.G., Lemes, P., Melo, A.S. & Loyola, R. 2014. The reduced effectiveness of protected areas under climate change threatens Atlantic Forest Tiger Moths. *PLoS One*, 9(9): e107792.

Gardner, T.A., Barlow, J., Chazdon, R., Ewers, R.M., Harvey, C.A., Peres, C.A. & Sodhi, N.S. 2009. Prospects for tropical forest biodiversity in a human-modified world. *Ecology Letters*, 12: 561–582.

Hobbs, R.J., Higgs, E., Hall, C.M., Bridgewater, P., Chapin III, F.S., Ellis, E.C., Ewel, J.J., Hallett, L.M., Harris, J., Hulvey, K.B., Jackson, S.T., Kennedy, P.L., Kueffer, C., Lach, L., Lantz, T.C., Lugo, A.E., Mascaro, J., Murphy, S.D., Nelson, C.R., Perring, M.P., Richardson, D.M., Seastedt, T.R., Standish, R.J., Starzomski, B.M., Suding, K.N., Tognetti, P.M., Yakob, L. & Yung, L. 2014. Managing the whole landscape: historical, hybrid, and novel ecosystems. *Frontiers in Ecology and the Environment*, 12(10): 557–564.

Latawiec, A.E., Strassburg, B.B.N., Brancalion, P.H.S., Rodrigues, R.R. & Gardner T. 2015. Creating space for large-scale restoration in tropical agricultural landscapes. *Frontiers in Ecology and the Environment*, 13: 211–218.

Laurance, W.F. 2009. Conserving the hottest of the hotspots. *Biological Conservation*, 142(6): 1137.

Loyola, R.D., Lemes, P., Faleiro, F.V., Trindade-Filho, J. & Machado, R.B. 2012. Severe loss of suitable climatic conditions for marsupial species in Brazil: challenges and opportunities for conservation. *PLoS One*, 7(9): e46257.

Maron, M., Hobbs, R.J., Moilanen, A., Matthews, J.W., Christie, K., Gardner, T.A., Keith, D.A., Lindenmayer, D.B. & McAlpine, C.A. 2012. Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation*, 155: 141–148.

Melo, F.P, Arroyo-Rodríguez, V., Fahrig, L., Martinez-Ramos, M. & Tabarelli, M. 2013a. On the hope for biodiversity-friendly tropical landscapes. *Trends in Ecology and Evolution*, 28: 462–468.

Melo, F.P.L., Pinto, S.R.R., Brancalion, P.H.S., Castro, P.S., Rodrigues, R.R., Aronson, J. & Tabarelli, M. 2013b. Priority setting for scaling-up tropical forest restoration projects: early lessons from the Atlantic Forest Restoration Pact. *Environmental Science & Policy*, 33: 395–404.

Menz, M.H.M., Dixon, K.W. & Hobbs, R.J. 2013. Hurdles and opportunities for landscape scale restoration. *Science*, 339: 526–527.

Pinto, S., Melo, F., Tabarelli, M., Padovesi, A., Mesquita, A., Scaramuzza, C.A., Castro, P., Carrascosa, H., Calmon, M., Rodrigues, R.R., César, G. & Brancalion, P.H.S. 2014. Governing and delivering a biome-wide restoration initiative: The case of Atlantic Forest Restoration Pact in Brazil. *Forests*, 5: 2212–2229.

Rappaport, D.I., Tambosi, L.R. & Metzger, J.P. 2015. A landscape triage approach: combining spatial and temporal dynamics to prioritize restoration and conservation. *Journal of Applied Ecology*, 52(3): 590–601.

Rey Benayas, J.M., Newton, A.C., Diaz, A. & Bullock, J.M. 2009. Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis. *Science*, 325: 1121–1124.

Ribeiro, M.C., Metzger, J.P., Martensen, A.C., Ponzoni, F.J. & Hirota, M.M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, 142: 1141–1153.

Rodrigues, R.R., Brancalion, P.H.S. & Isernhagen, I. 2009. *Pacto pela Restauração da Mata Atlântica: Referencial dos conceitos e ações de restauração florestal*. São Paulo, Brazil, Instituto BioAtlântica.

SCBD. 2014. *Global Biodiversity Outlook 4*. Montreal, Canada, CBD.

Tambosi, L.R., Martensen, A.C., Ribeiro, M.C. & Metzger, J.P. 2014. A framework to optimize biodiversity restoration efforts based on habitat amount and landscape connectivity. *Restoration Ecology*, 22: 169–177.

Thomas, E., Jalonen, R., Loo, J., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P. & Bozzano, M. 2014. Genetic considerations in ecosystem restoration using native tree species. *Forest Ecology and Management*, 333: 66–75.

UNEP–WCMC. 2014. *Global statistics from the World Database on Protected Areas (WDPA).* Cambridge, UK, UNEP–WCMC.

Veldman, J.W., Overbeck, G.E., Negreiros, D., Mahy, G., Le Stradic, S., Fernandes, G.W., Durigan, G., Buisson, E., Putz, F.E. & Bond, W.J. Tyranny of trees in grassy biomes. 2015. *Science*, 347(6221): 484–485. ◆

© EVERT THOMAS

Avoiding failure in forest restoration: the importance of genetically diverse and site-matched germplasm

E. Thomas, R. Jalonen, J. Loo and M. Bozzano

The likelihood of success of forest restoration can be improved by choosing genetically diverse forest reproductive material that is well adapted to the planting sites.

Evert Thomas is Associate Scientist with Bioversity International, Cali, Colombia.
Riina Jalonen is Associate Scientist with Bioversity International, Serdang, Malaysia.
Judy Loo is Scientific Domain Leader with Bioversity International, Maccarese, Italy.
Michele Bozzano is Scientist with Bioversity International, Maccarese, Italy.

INTRODUCTION

While the international community and individual countries have committed to restoring hundreds of millions of hectares of degraded forest landscapes,[1] the successes and failures of past restoration efforts remain poorly documented and communicated. This is a missed opportunity to learn from past experiences and to improve practices for better success rates and more efficient resource use in future restoration projects. Case studies demonstrate that failures may have been much more common than successes (Wuethrich, 2007; Godefroid *et al*., 2011). The causes of restoration failures can be manifold. One reason that is often overlooked is inadequate consideration of the source and genetic quality of forest reproductive material (FRM) (Godefroid *et al*., 2011; Le *et al*., 2012). Genetic diversity is positively related not only to

[1] https://www.cbd.int/sp/targets.http://www.un.org/climatechange/summit/wp-content/uploads/sites/2/2014/07/New-York-Declaration-on-Forest-%E2%80%93-Action-Statement-and-Action-Plan.pdf.

Above: Nursery seedlings produced for the establishment of a progeny trial with native species from tropical dry forest in Colombia

The result of restoration of a gold mine spoil in Cáceres, Colombia, 12 years after initiation (same site, before and after). The site was originally planted with diverse seed mixtures of 20 tree species (Moscoso Higuita, 2005) and now contains over 120 different native tree species and diverse wildlife, including jaguars, boa constrictors, sloths and several species of primates. This project has successfully attained certification for several standards such as the Verified Carbon Standard (VCS), Climate, Community and Biodiversity Standard and the gold standard, and it is currently trading verified carbon units (>400kt) on the international carbon market. With this, it became the first VCS project in South America, and the first ever in the world, with over 100 native tree species generating carbon credits (Thomas, 2014)

the fitness[2] of tree populations (Reed and Frankham, 2003; Schaberg *et al*., 2008) but also to wider ecosystem functioning and resilience (Gregorius, 1996; Reusch *et al*., 2005; Sgrò *et al*., 2011). Adequate attention to the genetic quality of FRM is particularly important for forest restoration, including tree-planting activities that aim to ''reinstate autogenic ecological processes by which species populations can self-organize into functional and resilient communities that adapt to changing conditions while at the same time delivering vital ecosystem services'' (Alexander *et al*., 2011).

The origin and genetic diversity of FRM significantly affect the survival, growth, and productivity of trees as well as the adaptive capacity and hence self-sustainability of tree populations (Reed and Frankham, 2003; Schaberg *et al*., 2008). In a meta-analysis of almost 250 plant species reintroductions worldwide, Godefroid *et al*. (2011) found that knowledge of the genetic diversity of the species introduced, and integrating that knowledge in seed sourcing, significantly enhanced the survival rate from the first year after reintroduction, and that this effect increased over time. The importance of using appropriate germplasm was recently highlighted by the 12th meeting of the Conference of the Parties to the Convention on Biological Diversity, which called for "due attention to both native species and genetic diversity in ecosystem conservation and restoration activities…" (Decision XII/19, 2014).[3]

CONSEQUENCES OF LOW GENETIC DIVERSITY OR INAPPROPRIATE ORIGIN OF FOREST REPRODUCTIVE MATERIAL

Two main considerations in the selection of FRM are crucial for bolstering the resilience of restored forests: planting material should be: (i) well-matched to the (present and predicted future) conditions of the planting site to ensure adaptedness; and (ii) sufficiently genetically diverse to avoid the adverse effects of inbreeding, provide sufficient genetic variants for natural selection to occur, and enhance the resistance of established populations to acute and chronic stressors, such as pests and diseases, as well as drought and other effects of progressive climate change.

Failure related to the use of poor-quality FRM may lead to high initial mortality, poor growth, susceptibility to biotic and abiotic stressors, and low reproductive success after the trees mature. High initial mortality is often witnessed within the planting or maintenance period of restoration projects and may be dealt with by replanting. However, the success of replanting depends on the underlying causes of mortality and how well these are addressed in further planting efforts. Most other types of failure become apparent later, often long after the project maintenance periods have ended, and are more difficult to mitigate. For example, poor growth or survival because of mismatched FRM or low genetic diversity may become increasingly apparent over decades. Delayed mortality resulting from susceptibility to biotic or abiotic stressors may manifest itself only after certain exceptional events. An example is the case of 30 000 ha of *Pinus pinaster* plantations, which were established in the Landes region of France with planting material from the Iberian

[2] For a definition of "fitness", see for example http://www.fao.org/DOcREP/003/X3910E/X3910E09.htm#TopOfPage.

[3] http://www.cbd.int/doc/decisions/cop-12/cop-12-dec-19-en.pdf.

peninsula that was susceptible to frost, and were destroyed during the exceptionally cold winter of 1984/1985 (Timbal *et al*., 2005).

The diversity of the first generation of trees plays a key role in the success of subsequent natural regeneration at a site. First-generation trees that are established by using FRM from genetically diverse source populations where the reproductive material is collected but from only one or a few genetically diverse mother trees will grow normally. However, many of the planted trees will be full or half siblings, resulting in inbred offspring in the next generation which may lead to reduced fitness (Reed and Frankham, 2003; McKay *et al*., 2005). The first signs of the deleterious effects of mating among relatives often become apparent when the trees reach reproductive age, with a drop in seed quality and quantity as well as decreased germination and seedling survival rates. In subsequent generations it may jeopardize the long-term viability and resilience of restored forests. For example, significantly reduced growth was observed in inbred second- and third-generation seedlings of *Acacia mangium* as compared to the mother trees that were originally introduced to Sabah (Malaysia) using FRM from Australia in 1967, and which had a very narrow genetic base (Sim, 1984). Inbreeding depression is more commonly expressed in more stressful environments, such as those characterized by the degraded soils found at most restoration sites (Fox and Reed, 2010). In the absence of an influx of new genes (e.g. through natural or human-influenced gene flow), this may lead to cascading effects over generations, increasing the risk of population and ecosystem collapse in the longer term owing to reduced vigour of trees, and a higher vulnerability to pests, pathogens and the effects of climate change. Similar problems occur when planting material is vegetatively propagated and originates from just a few trees.

In spite of these risks, insufficient consideration is given to the selection of appropriate planting material by restoration practitioners around the world (Bozzano *et al*., 2014). In the future, use of inadequate planting material may be an even more likely consequence of the limited restoration experience of many new actors emerging in response to major international commitments to restoration goals. Avoiding this will require the availability and mainstream use of user-friendly knowledge-based tools and protocols to guide restoration practitioners' choices of species and seed sources. If such tools and protocols are not followed, the choices can be expected to be predominantly opportunistic (i.e. focused on using easily accessible and available planting stock), at least in the short term. A survey of 23 restoration researchers and experts showed that species selection was more frequently based on the availability of planting material than, for example, on the conservation status of the species or their functional traits (Bozzano *et al*., 2014).

ENSURING THAT FRM IS GENETICALLY DIVERSE

Adaptation to changing site conditions occurs through natural selection. Effective natural selection depends upon: (i) genetic diversity in the traits that influence survival, growth and reproduction; (ii) the heritability of these traits; and (iii) large population sizes. When the intention is to establish self-sustaining forest ecosystems through restoration, it is pivotal that sourcing or collection of FRM is carried out in such a way as to capture a broad diversity in adaptively important traits for the target species. This means collecting seed from sufficiently large populations and from many unrelated mother trees, i.e. a minimum of 30–60 widely spaced trees or more if vegetative propagules are used (Kindt *et al*., 2006; Basey *et al*., 2015). Efforts should be made to avoid the successive use of seed collections from planted stands with low genetic diversity (Lengkeek *et al*., 2005), as this may exacerbate the effects of a narrow genetic base in subsequent populations. Also, where restoration relies mainly on natural regeneration, seed sources near the restoration site must be genetically diverse.

Guidelines for tree seed collection that aims to ensure a minimum level of genetic diversity exist, but appear to be largely unknown or overlooked by restoration practitioners or those who supply germplasm (Bozzano *et al*., 2014; Godefroid *et al*., 2011). This is probably partly because their implementation can be both time- and resource-demanding and partly because genetic homogeneity is not immediately visible while its negative effects become so only over time (Rogers and Montalvo, 2004; FAO, 1987; FAO, 2003; Palmberg, 1983).

An additional argument for the use of genetically diverse germplasm is that restored forests may later become seed sources for future restoration activities. Furthermore, if properly designed, restoration efforts offer cost-effective opportunities for conserving native tree species and their genetic variation (Sgrò *et al.,* 2011). This is particularly useful for rare, endemic or endangered species for which the availability of suitable germplasm is often very limited. Maintaining records of the sources of FRM is essential to inform decisions about future collection and management. Such records will also provide valuable information about the adaptability and viability of the original FRM used as the restored forests mature and their fitness can be evaluated (Rogers and Montalvo, 2004; Godefroid *et al*., 2011; Breed *et al*., 2013).

ENSURING ADAPTATION TO PLANTING SITE

Germplasm should not only be genetically diverse but also matched to the current and future conditions of the planting site. There is commonly a preference for planting stock from local sources (McKay *et al*., 2005; Sgrò *et al*., 2011; Breed *et al*., 2013). This is based on the assumption that local tree populations have undergone natural selection, thereby becoming optimally adapted to conditions of a nearby

Individuals of Parkia biglobosa *(Jacq.) G.Don (Leguminosae) in a provenance trial established by the National Tree Seed Center of Burkina Faso (CNSF) at the site of Gonsé in 1995. The trial included 15 provenances from across the range of the species. All trees were planted at the same time with planting material of different origin. The tree in the foreground shows signs of maladaptation to the environmental conditions at the planting site*

© B. VINCETI

restoration site, an assumption that is not always correct (McKay *et al*., 2005). Excessive emphasis on "local" germplasm may overlook the fact that geographical proximity to the restoration site is not necessarily the best indicator of the quality or suitability of germplasm. Local adaptation may, for example, be hindered by limited gene flow[4] or genetic drift[5] in small populations. In the degraded soils that often typify restoration sites, conditions may be very different from those under which local tree populations originally developed. Furthermore, environmental mosaics may result in geographically distant sites having similar conditions, while the conditions in nearby sites may be very different.

Ideally, the choice of the most suitable seed sources for a given restoration site is guided by provenance trials, if and when these exist. Provenance trials enhance our understanding of differences in responses by different genotypes grown in a particular environment. This is known as genotype by environment (GxE) interaction. Some genotypes may be very stable across a range of environments while others may perform much better in some environments than in others. The magnitude and type of GxE influence the distances across which planting materials can safely be moved from their local environments.

Provenance trials can be particularly useful in informing restoration practitioners about the scale and extent of local adaptation in tree species. Although many current provenance trials were not intentionally designed to characterize adaptive traits of different provenances, survival and growth are always assessed in such trials and these are basic measures of adaptation to the site where a trial is planted (Mátyás, 1994). They can help determine sources of planting material that are adapted to a particular site and the range within which reproductive material of a species can be moved without significant loss of adaptation (ecological tolerance limits).

[4] The exchange of genes between populations, usually through pollination and seed dispersal.

[5] A change in allele frequency from one generation to another within a population, due to the sampling of a finite number of genes that is inevitable in all finite-sized populations. The smaller the population, the greater is the genetic drift, with the result that some alleles are lost and genetic diversity is reduced. See for example http://www.bioversityinternational.org/uploads/tx_news/Forest_genetic_resources_conservation_and_management__overview__concepts_and_some_systematic_approaches__Vol._1_1018.pdf

Globally, some 700 tree species are subject to improvement programmes of some level, such as selection and provenance and/or progeny testing (FAO, 2014). While the oldest provenance trials were of temperate species, established both within and outside their natural ranges for industrial plantations, trials have also been established more recently for tropical species, including those that are important for the provision of non-wood forest products. Even if provenance trials do not exist at the time of planting, it is worth investing in their establishment, particularly in light of expected climate change, as they provide information about the adaptedness of the provenances to changing climate conditions over the lifespan of the planted trees. Ideally, provenance trials should cover the range of environments in which a species occurs and where it may be planted. The site conditions in a restoration area are often substantially different from those of the surrounding forests. Degraded sites may be more prone to drought, suffer from nutrient-depleted soil or lack other species that would normally be part of a functioning forest ecosystem. The establishment of future provenance trials should therefore also consider incorporating these factors.

In the absence of provenance trial data, suitability modelling and ecogeographical analyses of the environmental conditions at the planting site, as well as at the possible sites from which germplasm may be obtained, provide an alternative approach for selecting well-matched seed sources. If available, the genetic characterization of potential source populations through the application of molecular markers can provide complementary information on the genetic diversity profiles of these populations, as well as on the degree of genetic differentiation among them (Soldati *et al*., 2013; Azpilicueta *et al*., 2013). Recent advances in suitability modelling and the increasing availability of ever cheaper genotyping[6] techniques make it possible to better design restoration efforts at the landscape level, not only for matching FRM to restoration sites, but also for optimizing the connectivity of populations (McRae and Beier, 2007).

IMPROVING RESILIENCE TO CLIMATE CHANGE

Climate change will have a strong impact on many restoration sites. Yet currently few restoration practitioners appear to consider climate predictions in their design and implementation (Bozzano *et al*., 2014). Degraded forest sites typically constitute tough environments for seedling establishment and growth. When the climate

[6] The characterization of biological populations on the basis of DNA sequences through the use of molecular tools.

Emerging seedlings of the critically endangered tree species* Cariniana pyriformis *Miers (Lecythidaceae)

© EVERT THOMAS

simultaneously becomes harsher, natural or planted propagules experience even stronger selection pressure. Tree species generally have high genetic variation in adaptive traits, constituting latent adaptive potential which is expressed only when conditions change (Gamache and Payette, 2004; Alfaro *et al*., 2014). However, in many cases this may not be sufficient to ensure the long-term viability of local tree populations. The introduction of germplasm collected from more distant populations may therefore be necessary.

A growing number of studies recommend the use of seed from mixed sources to anticipate the potential impacts of climate change (Broadhurst *et al*., 2008; Sgrò *et al*., 2011; Breed *et al*., 2013). Decision trees have been developed to select the most appropriate seed-sourcing approach, depending on the evidence and confidence limits surrounding climate distribution modelling, and the knowledge of population genetic and/or environmental differences between populations (Breed *et al*., 2013; Byrne *et al*., 2011). If both GxE and expected climate change are known and expected to be low, a mix of germplasm obtained from local healthy tree populations may suffice. In the more usual cases where either GxE or climate change are unknown, *composite provenancing* has been proposed as a strategy to increase the adaptive potential of planting stock (Broadhurst *et al*., 2008; Sgrò *et al*., 2011; Breed *et al*., 2013). *Composite provenancing* aims to simulate natural gene flow dynamics by mixing: (i) a high proportion of material sourced locally from a range of environmental conditions in the same or neighbouring seed zones with (ii) a medium proportion of material that is sourced from intermediate distances and is ecologically matched (e.g. including planting material from warmer rather than cooler environments) and (iii) a low proportion of germplasm from distant populations that are ecologically diverse. For situations where there is a high probability of substantial climate change, but where the GxE interaction is less well known, an *admixture provenancing* approach has been proposed (Breed *et al*., 2013). In admixture provenancing, seed collection is focused on capturing a wide selection of genotypes from large populations occurring in various environments, with no spatial bias towards the revegetation site and no regard to gene-flow dynamics (Breed *et al*., 2013). This is intended to create a large, highly diverse gene pool so that natural selection can "choose" the best-adapted genotypes.

In some cases, habitat conditions are expected to be altered to such an extent by climate change and interacting factors, such as fragmentation due to land-use changes, that deliberate movement of FRM along environmental gradients, beyond the maximum distance of natural dispersal or pollen flow, may be necessary (Aitken *et al*., 2008; Sgrò *et al*., 2011). Ideally, translocation decisions should be based on solid field trial data. Provenance transfer based purely on climate distribution modelling is still controversial (Seddon, 2010; Sgrò *et al*., 2011). This is due to the uncertainties associated with both species distribution models and future climate models (Alfaro *et al*., 2014). In situations where no provenance trial data are available, the composite or admixture provenancing approaches described above may be more prudent (Breed *et al*., 2013).

AVAILABILITY AND SUPPLY OF PLANTING MATERIAL

By far the most commonly used planting material for restoration consists of nursery seedlings, partly because this increases the chances of successful establishment (Godefroid *et al*., 2011). As a consequence, the possibility of using optimal species combinations and germplasm that is both adapted to site conditions and genetically diverse is often limited in practice by what is available in commercial nurseries. Seed collectors and nurseries (private or public) are driven by economic considerations and produce what they expect to sell. Nursery managers often minimize the number of species they grow for reasons that may relate to the accessibility and availability of seed sources, efforts to simplify management, the risk of unsold production, or the lack of appropriate protocols for additional species (e.g. dormancy breaking) (Lillesø *et al*., 2011). A solution is to set up nurseries as a part of restoration efforts. This reduces the dependency of restoration practitioners on the vagaries and practicalities of supply from commercial nurseries, but requires adequate training of seed collectors and nursery staff to ensure that good-quality FRM is obtained.

Restoration practitioners who plan to obtain planting material from existing nurseries should communicate early with nursery managers to provide sufficient time for propagation of the desired species and to allow seed collection standards for genetic diversity to be met. Public authorities, for their part, should demand that nurseries and restoration practitioners demonstrate that they have applied due diligence in the collection and production of planting material to be used in restoration projects, which are often financed with public funds. Countries also need to invest more heavily in the establishment of functional seed distribution systems, to ensure the availability of appropriate planting material at any restoration site.

RECOMMENDATIONS

The targets for restoration should not only be quantitative. It is important that they also include qualitative aims to ensure that restored forest landscapes are resilient and self-sustaining. This means that adequate attention needs to be given to the origin and genetic diversity of FRM.

There is an urgent need for the further development, application and mainstreaming of user-friendly guidelines and protocols to assist emerging restoration practitioners with the choice of tree species and sources of FRM

There is also a need for strong political commitment to create a demand and ensure availability of seed from diverse, well-adapted sources of native species through regulatory frameworks and resource allocations. Publicly funded restoration projects should demand that nurseries apply due diligence with respect to the collection and production of planting material that is best adapted to target planting sites.

It is time for countries, particularly in the tropics, to invest in the establishment of provenance trials with native species across different environmental gradients, as these trials generate the most reliable data on the adaptedness of germplasm to particular sites and for predicting how this may change as a consequence of global warming.

It will be crucial to apply adaptive management by documenting and sharing not only successes but also mistakes and failures in forest and landscape restoration, both to accumulate existing knowledge and to continuously integrate new knowledge as it becomes available.

Acknowledgements

This article is adapted from: Thomas, E., Jalonen, R., Loo, J., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P. & Bozzano, M. 2014. Genetic considerations in ecosystem restoration using native tree species. *Forest Ecology and Management*, 333, 66–75. The preparation of this article, and the background Thematic Study (Bozzano *et al*., 2014) on which it is based, was supported by FAO and the CGIAR research programme “Forests, Trees and Agroforestry”. ◆

References

Aitken, S.N., Yeaman, S., Holliday, J.A., Wang, T. & Curtis-McLane, S. 2008. Adaptation, migration or extirpation: climate change outcomes for tree populations. *Evolutionary Applications*, 1(1): 95–111.

Alexander, S., Aronson, J., Clewell, A., Keenleyside, K., Higgs, E., Martinez, D., Murcia, C. & Nelson, C. 2011. Re-establishing an ecologically healthy relationship between nature and culture: the mission and vision of the Society for Ecological Restoration. *In* SCBD, ed. *Contribution of ecosystem restoration to the objectives of the CBD and a healthy planet for all people. Abstracts of posters presented at the 15th Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice of the Convention on Biological Diversity*, pp. 7–11. Montreal, Canada, SCBD.

Alfaro, R.I., Fady, B., Vendramin, G.G., Dawson, I.K., Fleming, R.A., Saenz-Romero, C., Lindig-Cisneros, R.A., Murdock, T., Vinceti, B., Navarro, C.M., Skrøppa, T., Baldinelli, G., El-Kassaby, Y.A. & Loo, J. 2014. The role of forest genetic resources in responding to biotic and abiotic factors in the context of anthropogenic climate change. *Journal of Forest Ecology and Management*, 333: 76–87.

Azpilicueta, M.M., Gallo, L.A., van Zonneveld, M., Thomas, E., Moreno, C. & Marchelli, P. 2013. Management of *Nothofagus* genetic resources: definition of genetic zones based on molecular data. *Forest Ecology and Management*, 302: 414–424.

Basey, A.C., Fant, J.B. & Kramer, A.T. 2015. Producing native plant materials for restoration: 10 rules to collect and maintain genetic diversity. *Native Plants Journal*, 16: 37–53.

Bozzano, M., Jalonen, R., Thomas, E., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P. & Loo, J. (eds). 2014. *Genetic considerations in ecosystem restoration using native tree species*. The State of the World’s Forest Genetic Resources – Thematic Study. Rome, FAO and Bioversity International.

Breed, M.F., Stead, M.G., Ottewell, K.M., Gardner, M.G. & Lowe, A.J. 2013. Which provenance and where? Seed sourcing strategies for revegetation in a changing environment. *Conservation Genetics*, 14: 1–10.

Broadhurst, L.M., Lowe, A., Coates, D.J., Cunningham, S.A., McDonald, M., Vesk, P.A. & Yates, C. 2008. Seed supply for broad-scale restoration: maximising evolutionary potential. *Evolutionary Applications*, 1: 587–597.

Byrne, M., Stone, L. & Millar, M.A. 2011. Assessing genetic risk in revegetation. *Journal of Applied Ecology*, 48: 1365–1373.

FAO. 1987. Information to be provided (to the extent possible) when ordering seeds for experimental purposes. *Forest Genetic Resources Information*, 15 (available at http://www.fao.org/docrep/006/s4009e/S4009E10.htm#ch10).

FAO. 2003. *Forest reproductive material: an overview*. Forest Genetic Resources Working Paper FGR/72E. Rome (available at http://www.fao.org/docrep/005/AD093E/AD093E00.HTM).

FAO. 2014. *The State of the World’s Forest Genetic Resources*. Rome.

Fox, C.W. & Reed, D.H. 2010. Inbreeding depression increases with environmental stress: an experimental study and meta-analysis. *Evolution*, 65: 246–258.

Gamache, I. & Payette, S. 2004. Height growth response of tree line black spruce to recent climate warming across the forest-tundra of eastern Canada. *Journal of Ecology*, 92: 835–845.

Godefroid, S., Piazza, C., Rossi, G., Buord, S., Stevens, A.-D., Aguraiuja, R., Cowell, C., Weekley, C.W., Vogg, G., Iriondo, J., Johnson, I., Dixon, B., Gordon, D., Magnanon, S., Valentin, B., Bjureke, K., Koopman, R., Vicens, M., Virevair, M. & Vanderborght, T. 2011. How successful are plant species reintroductions? *Biological Conservation*, 144(2): 672–682.

Gregorius, H. 1996. The contribution of the genetics of populations to ecosystem stability. *Silvae Genetica*, 45: 267–271.

Kindt, R., Lilleso, J.P.B., Mbora, A., Muriuki, J., Wambugu, C., Frost, W., Beniest, J., Aithal, A., Awimbo, J., Rao, S. & Holding-Anyonge, C. 2006. *Tree seeds for farmers: a toolkit and reference source*. Nairobi, World Agroforestry Centre (available at: http://www.worldagroforestry.org/sites/default/files/Toolkit.pdf).

Lamb, D. 2012. Forest restoration – the third big silvicultural challenge. *Journal of Tropical Forest Science*, 24: 295–299.

Le, H.D., Smith, C., Herbohn, J. & Harrison, S. 2012. More than just trees: assessing reforestation success in tropical developing countries. *Journal of Rural Studies*, 28: 5–19.

Lengkeek, A., Jaenicke, H. & Dawson, I. 2005. Genetic bottlenecks in agroforestry systems: results of tree nursery surveys in East Africa. *Agroforestry Systems*, 63: 149–155.

Lillesø, J.-P.B., Graudal, L., Moestrup, S., Kjær, E.D., Kindt, R., Mbora, A., Dawson, I., Muriuki, J., Ræbild, A. & Jamnadass, R. 2011. Innovation in input supply systems in smallholder agroforestry: seed sources, supply chains and support systems. *Agroforestry Systems*, 83: 347–359.

Mátyás, C. 1994. Modeling climate change effects with provenance test data. *Tree Physiology*, 14: 797–804.

McKay, J.K., Christian, C.E., Harrison, S. & Rice, K.J. 2005. "How local is local?" A review of practical and conceptual issues in the genetics of restoration. *Restoration Ecology*, 13, 432–440.

McRae, B.H. & Beier, P. 2007. Circuit theory predicts gene flow in plant and animal populations. *Proceedings of the National Academy of Sciences USA*, 104: 19885–19890.

Moscoso Higuita, L. 2005. Reforestation: a natural process. Medellín, Colombia, Editorial Colina.

Palmberg, C. 1983. FAO guidelines for seed ordering. *Forest Genetic Resources Information*, 12 (available at http://www.fao.org/docrep/006/q5987e/Q5987E15.htm#ch15).

Reed, D.H. & Frankham, R. 2003. Correlation between fitness and genetic diversity. *Conservation Biology*, 17: 230–237.

Reusch, T., Ehler, A., Hammerli, A. & Worm, B. 2005. Ecosystem recovery after climatic extremes enhanced by genetic diversity. *Proceedings of the National Academy of Sciences USA*, 102: 2826–2831.

Rogers, D.L. & Montalvo, A.M. 2004. *Genetically appropriate choices for plant materials to maintain biological diversity*. Report to the USDA Forest Service. Rocky Mountain Region, Lakewood, University of California.

Schaberg, P., DeHayes, D., Hawley, G. & Nijensohn, S. 2008. Anthropogenic alterations of genetic diversity within tree populations: implications for forest ecosystem resilience. *Forest Ecology and Management*, 256: 855–862.

Seddon, P. 2010. From reintroduction to assisted colonization: moving along the conservation translocation spectrum. *Restoration Ecology*, 18: 796–802.

Sgrò, C.M., Lowe, A.J. & Hoffmann, A.A. 2011. Building evolutionary resilience for conserving biodiversity under climate change. *Evolutionary Applications*, 4: 326–337.

Sim, B.L. 1984. The genetic base of *Acacia mangium* Willd. in Sabah. In R.D. Barnes & G.L. Gibson, eds. *Provenance and genetic improvement strategies in tropical forest trees*, pp. 597–603. Mutare, Zimbabwe and Oxford, UK, Commonwealth Forestry Institute; Harare, Zimbabwe, Forest Research Centre.

Soldati, M.C., Fornes, L., Van Zonneveld, M., Thomas, E. & Zelener, N. 2013. An assessment of the genetic diversity of *Cedrela balansae* (Meliaceae) in northwest Argentina by means of combined use of SSR and AFLP molecular markers. *Biochemical Systematics and Ecology*, 47: 45–55.

Thomas, E. 2014. Forest devastated by mining is reborn. *Nature*, 511: 155.

Timbal, J., Bonneau, M., Landmann, G., Trouvilliez, J. & Bouhot-Delduc, L. 2005. European non-boreal conifer forests. *In* F.A. Andersson, ed. *Ecosystems of the world (6): Coniferous forests*, pp. 131–162. Amsterdam, Netherlands, Elsevier.

Wuethrich, B. 2007. Biodiversity. Reconstructing Brazil's Atlantic rainforest. *Science*, 315: 1070–1072. ◆

©FAO/GIULIO NAPOLITANO

Restoration of degraded forests and landscapes in drylands: guidelines and way forward

N. Berrahmouni, M. Parfondry, P. Regato and A. Sarre

Forests are a key source of resilience in drylands; however, large areas of dryland forests and woodlands are degraded and need to be urgently restored.

Nora Berrahmouni is Forestry Officer (Drylands) in FAO's Forestry Department.
Marc Parfondry is Forestry Expert with the FAO Forestry Drylands programme.
Pedro Regato is a biologist with a PhD in forest ecology, currently working as an international consultant with FAO, IFAD, WWF, BirdLife and other organizations.
Alastair Sarre is is a writer, editor and policy analyst specializing in international forest policy.

WHAT ARE DRYLANDS AND WHY DO THEY NEED TO BE RESTORED?

Drylands are characterized by a scarcity of water, which affects both natural and managed ecosystems and constrains the production of livestock as well as crops, forage, wood, and other ecosystem services (MEA, 2005). Representing 41 percent of the Earth's land surface and home to 2 billion people (UNDP and UNCCD, 2011), drylands face numerous challenges. Changing land uses and practices such as the transformation of rangelands and other silvopastoral systems to cultivated croplands, wasteful and unsustainable water use, unsustainable cultivation and grazing practices, and the overharvesting of forest resources including for woodfuel and non-wood forest products, are leading to land degradation and desertification, water shortages and major losses of ecosystem services. An estimated 10–20 percent of the world's drylands suffer from one or more forms of land degradation (MEA, 2005) and climate change is expected to increase the incidence of extreme weather events such as droughts and to exacerbate desertification and declining land productivity.

Above: Water scarcity – pastoralists and herds of livestock gathering at a water well in a dry portion of Lake Magadi, Kenya

Because of the crucial ecological, social and economic roles they play in drylands, forests, agrosilvopastoral systems and trees are essential to tackling the above-mentioned challenges. They are also a source of resilience in the face of climate change and variability – the complex interactions, effects, and feedback between climate-change trends, human population growth and consumption, energy use, land-use changes and pollution. Large areas of dryland forests and woodlands are degraded, however, and there is an urgent need for their restoration.

Restoration actions in drylands could range from on-the-ground activities such as habitat protection, sustainable natural resource management, assisted natural regeneration, sand-dune stabilization, seeding and planting of trees, shrubs and grasses for multiple purposes, to policy improvements, the provision of financial incentives, capacity development, and continuous monitoring and learning. To be effective and sustainable, dryland restoration should be approached at the landscape level, as the functionality and sustainability of drylands – both in ecological and socio-economic terms – more than anywhere else depend on the seasonal availability of limited resources such as water and biomass over large territories, and the long-distance movements (e.g. upland–lowland transhumance or other long-distance spatial movements linked to a nomadic lifestyle) and strategies that people, livestock and wildlife have developed over the ages to access them and ensure both ecological and socioeconomic sustainability.

A COUNTRY-DRIVEN AND COLLABORATIVE PROCESS: ASSESSING, MONITORING AND LEARNING

At the request of member countries, FAO, together with partners, launched the Drylands Restoration Initiative with the aim of capturing, evaluating and sharing knowledge gained in dryland restoration initiatives worldwide. This process resulted in the compilation of *Global guidelines for the restoration of degraded forests and landscapes in drylands* to help improve livelihoods and strengthen the resilience of forests and landscapes in drylands. The guidelines aim to promote and enhance restoration efforts in the world's drylands. They provide specific guidance for policy-makers and other decision-makers, as well as for practitioners.

This article summarizes the main elements of the guidelines.[1]

The process to produce the guidelines began in May 2012 in Konya, Turkey, at the international workshop "Building resilient forest landscapes to global changes in drylands". The workshop brought together more than 90 international experts on dryland restoration from forestry departments, research institutions, the private sector, non-governmental organizations (NGOs), international development agencies and other technical and financial partners representing 24 countries in Africa, Central Asia, the Near East and

[1] The complete publication can be accessed at http://www.fao.org/3/a-i5036e.pdf.

©BIOVERSITY/MICHELE BOZZANO

Dakar international workshop participants testing the guidelines with local people in Mboula in the Great Green Wall area, Senegal, February 2013

the Mediterranean region. A second international workshop was convened in Dakar, Senegal, in February 2013 and gathered more than 80 international experts on dryland restoration. Both workshops provided a forum for experts to analyse lessons learned from afforestation, reforestation and restoration projects and programmes in the field, allowing the delivery of robust, experience-based recommendations. Furthermore lessons learned from a number of case studies provided by experts and compiled through desk research work were used to illustrate the guidelines. These case studies were compiled through the application of a Monitoring and Reporting Tool for Forest and Landscape Restoration, developed by FAO with contributions from workshop participants, experts and practitioners. Finally, draft versions received feedback from a network of experts through online consultation and the organization of side-events.

To advance drylands monitoring and assessment for restoration and sustainable management, FAO hosted in January 2015 the first Drylands Monitoring Week co-organized with partners including the World Resources Institute (WRI) and the International Union for Conservation of Nature (IUCN) with funding support from the European Union (EU) and the Global Environment Facility (GEF). During this week, participants reviewed a wide range of methods and tools for monitoring and assessing different aspects of drylands, as well as emerging new technologies. Participants raised their concern about the inadequacy of the current state of the art, including insufficient scale of application, lack of capacity, and gaps in existing monitoring systems. They called for the development of more comprehensive and cost-effective methods, including using existing methods and tools as building blocks and developing new methods integrating remote sensing and local participation. Participants issued the Rome Promise,[2] which includes collaborative action such as the formation of an open-ended collaborative network or community of practice to advance monitoring and assessment of drylands.

By measuring progress over time, monitoring and evaluation provides an evidence base on which strategies can be built and adapted, thereby helping build resilience. Monitoring and evaluation in restoration initiatives should be integrated into every restoration initiative, including:

- developing the monitoring plan or programme in the planning phase;
- promoting the participation of all stakeholders in the design and implementation of monitoring; and
- consistently monitoring and evaluating restoration initiatives and sharing the lessons learned for the benefit of ongoing and future initiatives.

KEY FINDINGS: THE *GUIDELINES* IN A NUTSHELL

The guidelines provide guidance for two main types of users: (i) policymakers and other decision-makers, labelled as "enablers", as they provide the appropriate policies, governance mechanisms and financial and other incentives; and (ii) practitioners, who are the "doers" of restoration.

Guidance for policymakers and decision-makers

Possible actions and recommendations are proposed for implementing and sustaining effective restoration efforts, including policy, governance, multisectoral planning, and financial and other incentives. Key messages include the need to:

- *Enable and invest in assessment and monitoring* – improved monitoring and assessment are essential to assess restoration needs, identify priority areas, estimate the required level of financial and technical investment, and ensure continued progress of restoration efforts.
- *Address drivers of land degradation by engaging in cross-sectoral dialogue and planning at the landscape level* – a lack of intersectoral coordination often means that different institutions treat various components of land management and restoration separately, limiting their capacity to address the drivers of degradation associated with competing land uses. Multisectoral platforms can be used to raise awareness of the extent and negative impacts of dryland degradation, encourage intersectoral approaches for addressing dryland degradation, and demonstrate restoration benefits and returns on investment.
- *Enable and invest in capacity assessment and development* – in many countries with drylands there is an urgent need for more qualified practitioners who can deliver restoration competently and effectively, and also a need to develop networks of communicators and opinion leaders to influence policymakers. Ensuring the required capacities should be part of the initial planning of restoration initiatives, and the first step is capacity assessment. FAO capacity-development tools can be adapted and used for such assessments.
- *Improve the supply of, and access to, plant reproductive material for restoration* – national seed centres and programmes should be developed and strengthened to ensure the availability of genetically appropriate seeds in the quantities and quality needed for restoration.
- *Improve the governance and policy framework* – an enabling policy framework needs to be in place to encourage restoration and avoid perverse policies that drive degradation. Secure land tenure is particularly important for achieving sustainable land management and boosting livelihoods. Local- and national-level institutions should also support local processes by providing adequate governance structures and policies, encouraging the equitable participation of stakeholders, and ensuring the necessary technical and financial support.

[2] http://www.fao.org/forestry/42520-09d6892b4a39725e9bb54c2d37988567f.pdf.

- *Creating the right conditions for investment and resource mobilization for restoration* – sufficient investments are required to initiate and sustain restoration activities, and these may come from a variety of stakeholders. Local-level investments can be promoted in different ways, and small-scale, locally driven tree and forest product enterprises can broaden local income opportunities through restoration.
- *Encourage knowledge, research, learning and experimenting* – developing collaborative and adaptive learning and experimenting processes based on traditional knowledge and innovative research, and promoting the sharing of knowledge among land users, are keys for successful restoration.

Guidelines for practitioners highlight the need to:

- *Plan and choose the most cost-effective restoration strategies* – involving communities in the planning of restoration strategies can be effective in formulating restoration interventions and sustainable goals that address the needs of all stakeholders. Non-degraded areas can be used as reference sites for defining restoration goals and assessing the progress and impacts of restoration activities. Landscape-scale planning takes into account the mosaic of land uses and the diversity of needs of all stakeholders. Diverse restoration strategies should be promoted, and planting is often only one of several possible activities.
- *Protect and manage* – improvements in protection and management are potentially more cost-effective than planting in restoration initiatives. A good starting point is to protect soils against erosion, use cost-efficient water-harvesting techniques and mainstream the use of integrated management plans to address threats such as excessive wood collection, unplanned grazing, and damaging fire, pests and diseases.
- *Promote natural regeneration* – assisted natural regeneration and, on farms, farmer-managed natural regeneration are simple and effective restoration measures that require little investment. They also have the potential to be scaled up quickly in areas where tree and shrub species have the ability to re-sprout after harvest and where appropriate rights to resource use exist.
- *Plant where necessary* – if a planting strategy is needed, the choice of species should be made according to clear criteria and local preferences and uses. Special attention should be given to using the right species in the right place, including – where appropriate – trees, shrubs and grasses and ensuring the quality of genetic material. Native species should be favoured. The number of species, and their genetic diversity, should be maximized as a way of enhancing resilience. Adequate nursery techniques should be employed, and planting times and densities should be chosen carefully to ensure optimal use of limited water resources.

The example provided in the box below gives an illustration of research institutions (the Royal Botanic Gardens Kew, and the Universidad Nacional San Luis Gonzaga de Ica) working together and hand in hand with local communities and businesses to promote the use of native species in the restoration of Peruvian dry forests. The initiative combined research, community-based techniques and used extension, awareness-raising and capacity development at the local level.

©FAO/MOUSTAPHA OULD MOHAMED

Installing a palisade, mechanical dune stabilization, Mauritania

©PEDRO REGATO

A mosaic of land uses within a landscape: fynbos, karroid shrublands, vineyards, pastures and forests in the Outeniqua Mountains, South Africa

THE WAY FORWARD

FAO will work with practitioners, experts, policymakers and other decision-makers, as well as other partners and member countries, to widen and facilitate the community of restoration enablers and build bridges between practitioners and policymakers to boost the implementation of the guidelines. A major effort is also needed to strengthen local governance and develop local leaders and restoration champions, which can be done by helping strengthen community-based organizations, local administrations, forest producer organizations and community enterprises. FAO will promote and disseminate these guidelines and opportunities for adapting them to regional, national and local contexts and implementing them on the ground.

Major restoration initiatives worldwide in which FAO is involved include GEF co-funded restoration projects in dryland countries as well as the EU-ACP (African, Caribbean and Pacific region) co-funded Action Against Desertification project in support of the Great Green Wall for the Sahara and the Sahel Initiative and the United Nations Convention to Combat Desertification (UNCCD) Action Plans in eight countries across Africa, the Caribbean and the Pacific. Such projects are an excellent option for complementing domestic efforts to implement the guidelines.

Many national, regional and global research networks are active in dryland regions. It is essential to create linkages between such networks, restoration practitioners and communities as a way of applying research results on the ground and combining new learning with traditional practices.

The Rome Promise, which was adopted in early 2015, is a call to action to improve the monitoring and assessment of drylands for their sustainable management and restoration. The first global assessment of drylands, now underway, is an initial step in the implementation of the Rome Promise and will build a robust baseline to support restoration monitoring efforts and the further development of these guidelines over time. ◆

References

FAO. 2015. *Global guidelines for the restoration of degraded forests and landscapes in drylands: building resilience and benefiting livelihoods*. Forestry Paper No. 175. Rome.

FAO. n.d.a. Drylands Restoration Initiative website (available at www.fao.org/forestry/aridzone/restoration).

FAO. n.d.b. Drylands Monitoring Week website (available at www.fao.org/forestry/aridzone/88626/en).

FAO. n.d.c. Action Against Desertification website (available at www.fao.org/in-action/action-against-desertification/en/).

MEA. 2005. *Millenium ecosystem assessment: ecosystems and human well-being: current state and trends*. Volume 1, Chapter 22. Millennium Ecosytems Assessment. Washington DC, World Resources Institute.

UNDP & UNCCD. 2011. *The forgotten billion: MDG achievement in the drylands*. Bonn, United Nations Convention to Combat Desertification and United Nations Development Programme.

Whaley, O.Q., Beresford-Jones, D.G., Milliken, W., Orellana, A., Smyk, A. & Leguía, J. 2010. An ecosystem approach to restoration and sustainable management of dry forest in southern Peru. *Kew Bulletin*, 65: 613–641. ◆

© O. WHALEY

Restoration activities, Ica, Peru

Use of native species for the restoration and the sustainable use of southern Peruvian dry forests

The initiative was led by the Royal Botanic Gardens, Kew, supported by the United Kingdom's Department for Environment, Food and Rural Affairs' Darwin Initiative and the Universidad Nacional San Luis Gonzaga de Ica (UNICA).

This case study illustrates community-based restoration techniques – with the active involvement of local policymakers – used for the restoration of the natural riparian dry habitats that play vital roles as corridors between the Andean foothills and the coastal plains. The project has raised awareness among landowners, businesses and the regional government of the importance of plant conservation in the restoration of people's quality of life by demonstrating the income opportunities from tourism and the use of keystone *Prosopis* spp. (huarango) tree pods.

Restoration trials were established in three small local communities and at three agro-industrial sites. A memorandum of understanding was signed with UNICA's Faculty of Agronomy for the establishment of a plant nursery to produce seedlings of 30 native species from seeds and cuttings. In the local community restoration trials, areas were fenced in agreement with landowners, seedlings were planted and irrigated with water from nearby wells, and empty tree pits were irrigated to encourage natural regeneration. In the agro-industrial trial, native woodland species were planted to replace non-native species in windbreaks and hedgerows using drip-feed irrigation. Native species were established in comparative plots using low-consumption drip-feed, manual surface and subsurface irrigation regimes and grey (sewage) water. In addition to watering regimes, the trials compared planting techniques and densities. Locally referenced habitat restoration, including measures to attract birds, was also carried out, and drip-feed irrigation and traditional tree-pit watering were compared.

Community involvement

- Reconnecting people and plants is a prerequisite for project sustainability. Communication and education efforts (e.g. media dissemination, lectures, learning tours, planting campaigns, and the Huarango Festival)[1] were maintained in local communities, with an emphasis on engaging youth. A school programme run by the non-governmental organization (NGO) Asociación para la Niñez y su Ambiente (ANIA) and local women to establish nurseries for native plants was an effective way of fostering the project's goals; the schools became hubs from which project staff were able to distribute seeds, information and technical advice on native trees and shrubs and the environmental services they provide to the families of schoolchildren and those landowners able to demonstrate sustainable water supplies.
- Restoring traditional know-how and techniques on seasonal floodwater-harvesting has the capacity to regenerate communities and cultures.

[1] The Huarango Festival promotes cultural connections with the environment through the emblematic tree of Ica, including banquets offering products from native plant species.

Extension/training methodologies

Extension and training involved workshops, local school programmes and festivals, supported with posters, handouts and didactic publications for local audiences. Staff at the Millennium Seed Bank Partnership and the Royal Botanic Gardens Kew, also provided training in the development of low-cost seed storage, germination and propagation protocols.

Research

Research comprised botanical surveys, flora and fauna inventories and maps incorporating local ethnobotanical knowledge of the ten distinct vegetation communities occurring between sea level and 1 800 m, including the vitally important and poorly understood N-fixing microphytic communities of biological crusts.

Technological development

Technologies developed under the project included the following:

- During the fog season, fine nets were able to trap, on average, 10 litres of fog water per day per m^2 of net (a *Prosopis* tree with a 3 x 4-m crown captured up to 9 litres per night).
- Traditional techniques were incorporated into practices (i.e. in schools' planting programmes), such as the use of "coated seeds" whereby clumps of mud and mixtures of seeds of native species are baked, dried and buried in the courses of irrigation channels and ephemeral streams to await natural flooding.
- In comparing irrigation regimes, it was determined that an inexpensive subsurface watering technique developed by the project using recycled plastic bottles to dispense 3–4 litres per week provided the best growth (by height and canopy area); compared with traditional tree pit-watering, the growth of *Prosopis* increased by more than 100 percent, *Acacia* by 20 percent and *Schinus* by 300 percent. This subsurface method thus proved an excellent way of avoiding excessive evaporation.

Results

The local community trials achieved mixed results in terms of plant survival (for example, *Schinus molle* and *Acacia macracantha* became well established, but *Capparis avicennifolia* proved difficult to grow), with survival challenged by shallow soils and water constraints. Pumping water proved uneconomic, and soils were nutrient-deficient. Viable restoration should be based on rebuilding the river-flooding system with traditional know-how and techniques. Collective labour or machinery is required to move boulders into riverbeds to raise the water level and to capture sediments during seasonal floods, thereby reconnecting river flow with irrigation channel intakes. This technique may have considerably wider application in large-scale restoration.

In the agro-industry trials, the project involved industry workers in the planning and field-planting of a 3-ha site with 24 native species, thereby helping the dissemination of local knowledge to workers. Under a low watering regime (1 litre per week) with an asparagus "straw" mulch, *Acacia macracantha*, *Schinus molle* and *Prosopis limensis* seedlings showed double the height growth and three times the canopy area as compared with the control. Sewage dumping allowed the establishment of a high-biodiversity grove of *Prosopis limensis* and *Parkinsonia praecox* featuring birds, desert foxes and native bees. Planting densities affected height growth and canopy area in different ways, according to species: for example, the canopy area of *Prosopis limensis* doubled when grown at a low density compared with the highest-density plantings; *A. macracantha* height growth in low-density plantings was double that of high-density plantings; and *S. molle* height growth was ten times greater in high-density plantings than in the low-density plantings. The installation of bird perches and nesting poles attracted 39 bird species acting as pollinators and seed-dispersers and facilitating the recruitment of new plant species (70 new plant species appeared naturally where drip-feed lines provided sufficient humidity). The introduction of native plants promoted a significant increase in the biocontrol of pests by predator insects and birds.

Sustainability

The project's tree nursery continues to be funded by Trees for Cities (a British NGO) and ANIA, and a UNICA graduate has set up a successful private tree nursery for native species. The Huarango Festival is now organized under the auspices of the Ministry of Tourism and is firmly established in the official calendar. Most municipalities are now aware of the importance of native woodlands and are using native species instead of ornamental trees. Several publications promote the many undervalued plant species of the region and their importance for human well-being and livelihoods. International media events have helped promote local pride and interest in culture–environment links and create tourism development opportunities. The involvement of agro-industries in the restoration programme has helped enlarge restoration efforts and secure further funding, mainly for incorporating restoration objectives in production operations.

Source: Whaley *et al*., 2010.

Community participation at the heart of Africa's Great Green Wall restoration model[1]

M. Sacande, N. Berrahmouni and S. Hargreaves

Building on past restoration experiences, Africa's Great Green Wall for the Sahara and the Sahel Initiative is taking shape, with the "wall" a metaphor for a mosaic of sustainable restoration and rural development activities.

Moctar Sacande is a forest seed physiologist and dryland restoration expert. He is leading the Great Green Wall restoration project in West Africa and working as Research Leader in the Natural Capital Department of the Royal Botanic Gardens, Kew, United Kingdom.
Nora Berrahmouni is a forest ecologist, working as Forestry Officer for the Drylands in FAO's Forestry Department, Rome, Italy.
Serene Hargreaves, an expert in conservation genetics, is the Great Green Wall Project Officer at the Royal Botanic Gardens, Kew, United Kingdom.

INTRODUCTION, SCOPE AND MAIN OBJECTIVES

Dryland forests and agrosilvopastoral systems in the Sahel are the source of a wide range of ecosystem services on which local communities depend. Under pressure from increasing demand, natural resources are being overexploited, which in turn is leading to degradation and desertification, putting the world's most vulnerable people at risk. Although a simplification, the vicious cycle of land degradation holds true in many cases, where the inappropriate use of marginal lands is leading to a decline in productivity and consequent increase in poverty (Bremner *et al*., 2010).

Sub-Saharan Africa is believed to be one of the regions most vulnerable to climate change (Nakhooda *et al*., 2011; Fingar, 2008). Increasing temperatures and changing precipitation regimes are projected to exacerbate natural hazards, accelerate desertification, increase exposure to infectious diseases, compromise food and water security and accelerate the degradation of ecosystem services (IPCC, 2014). Given the inevitability of some degree of climate

[1] This article is based on the paper of the same title that was submitted to the XIV World Forestry Congress, Durban, South Africa, September 2015.

A Great Green Wall village technicians' tree nursery close to the planting site in Djibo, Burkina Faso

© MOCTAR SACANDE

change and the impacts already observed, the Great Green Wall (GGW) for the Sahara and the Sahel Initiative supports the adaptation and resilience of natural and human systems. Endorsed in 2007 by the African Union, the programme addresses environmental and development issues through sustainable land-management approaches tailored to the context of the local communities and local environment. The priority interventions defined by the GGW notably include restoration of forest landscapes and degraded lands (Berrahmouni *et al*., 2014; AUC/PAGGW, 2012).

FAO, with the financial contribution of the European Union and the countries of the African, Caribbean and Pacific Group of States (EU-ACP), is supporting the African Union Commission in delivering this ambitious initiative, with the contributions of numerous other organizations, governments, partners and stakeholders on the ground. As part of this collaboration, the Royal Botanic Gardens (RBG), Kew, is using its botanical knowledge and information resources, as well as engaging with in-country partners and local communities, to identify priority native species for the GGW that meet communities' needs in addition to being well adapted to the dryland ecosystems. To date, the intervention has directly benefited 110 communities in four transborder regions of Burkina Faso, Mali and the Niger. Propagation and restoration efforts have resulted in the planting and maintaining of over 1 million seedlings and seeds of 50 useful native woody and herbaceous species. Now in its third year, this model restoration project has helped communities restore over 1 000 ha of degraded land. Scientific expertise, efficient technology transfer and capacity strengthening in plant knowledge have been the core of the success of the GGW restoration activities in these countries.

This article looks at the restoration programmes in four cross-border regions of the GGW: Bankass in Mali; Dori and Djibo in Burkina Faso; and Tera in the Niger. It focuses on the restoration model, with the planting of environmentally well-adapted and economically useful local plant species in agrosylvopastoral systems, including tree, shrub and herbaceous species.

METHODOLOGY

Selection of villages

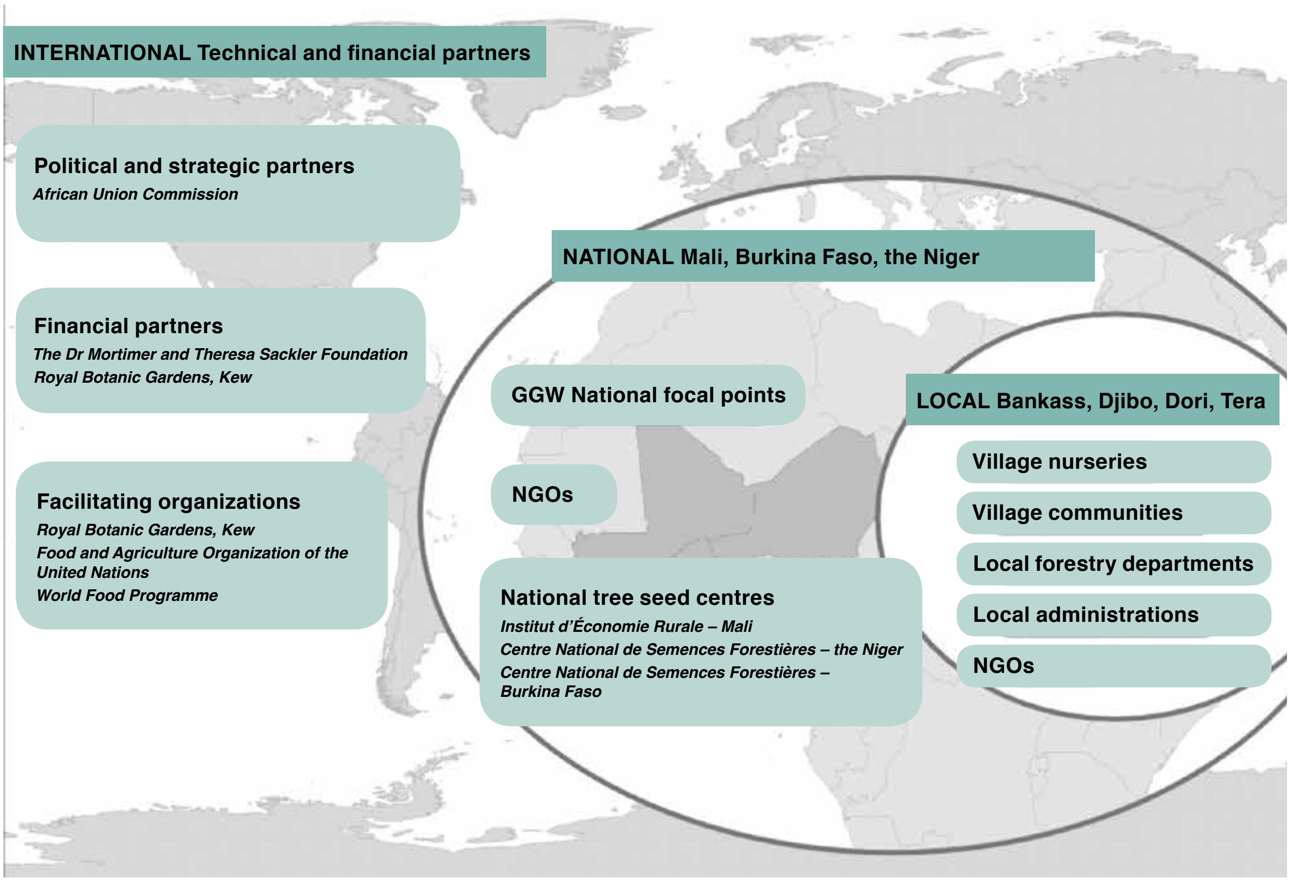
The selection criteria for participation in the pilot project included: (a) existence in the villages of degraded land available for planting and land reclamation; (b) motivation and commitment to participate in restoration activities, including in-kind contributions; (c) social diversity of village beneficiaries (gender, age, profession, etc.), community-based structure and organization; and (d) the availability of relevant facilities, for example water sources for installing a village nursery, or opportunities for work with other ongoing programmes/projects in the villages and/or region.

Community participation in prioritizing species

Following the selection of participant communities, village consultation workshops are set up with all involved parties. This provides an understanding of local needs and species uses and preferences, and enables agreement on restoration objectives from the communities' perspective.

© MOCTAR SACANDE

Soil preparation for Great Green Wall planting, Tera community, the Niger



Source: Great Green Wall Transboundary Project, Kew.

1
Key relationships at each level within the GGW pilot restoration project. A list of partners involved in the GGW programme can be found at http://www.fao.org/in-action/action-against-desertification/en/

Consultation is a critical initial step, as the communities contribute and commit their managed land and labour for implementing the planned activities.

Botanical research is undertaken on the lists of requested species, prioritizing species on the basis of availability, knowledge of seed handling, germination and propagation, speed of return of products for the local communities and adaptation to local environments.

Implementation on the ground and monitoring

Implementation on the ground includes the acquisition of quality seed collections from selected natural stands to capture the genetic diversity of the population sampled and ensure that seed materials are of high physiological quality. Seedlings of native woody species are produced in village nurseries, and are ready to be planted out within a year. To enable the retention of maximum moisture from limited rainfalls and thereby maintain moist soil for the longest possible period, traditional techniques of "half-moon" or "*zaï*" cultivation are used. This stops water run-off and allows water harvesting by creating multiple small dams in the field, giving seeds and seedlings a better chance to establish. Land scarification is also applied in wider inter-village areas. The planting of seeds and seedlings takes place at the onset of and during the rainy seasons, generally in June and July in the intervention areas, so that the plants receive maximum benefit from rainwater.

Monitoring and field data collection on the survival and growth of seedlings are carried out by trained village technicians in collaboration with the communities and the technical institutions. A technical management team is set up, bringing together representatives of all stakeholder groups, from recipient beneficiaries and communities to local environmental non-governmental organizations (NGOs), technical facilitators and sponsors (Figure 1). The team meets once a year to evaluate and plan for restoration activities, assessing progress and defining roles, responsibilities, accountabilities and reporting. Capacity development targets local farmers, village technicians and community representatives, and covers quality seed collection in defined seed zones by the

TABLE 1. Achievements of the GGW pilot project, including beneficiaries, restored area and seedlings planted in 2013 and 2014

Country	Region	2013					2014				
		Number of beneficiary villages	Restoration data				Number of beneficiary villages	Restoration data			
			Planted area (ha)	Species used	Seedlings planted	Seeds (kg)		Planted area (ha)	Species used	Seedlings planted	Seeds (kg)
Mali	Bankass	5	65	10	35 700	18	4	36	19	15 100	128
Burkina Faso	Djibo	–	–	–	–	–	41	195	5	42 150	–
	Dori	11	200	15	111 500	16	30	384	8	239 700	–
the Niger	Tera	5	55	1	30 000	–	14	214.2	7	71 121	66
Total		**21**	**320**	**26**	**177 200**	**34**	**89**	**829.2**	**39**	**368 071**	**194**

national forest seed centres, land preparation, seedling production, planting and woodland enrichment, and participatory forest management.

RESULTS

Technical management and operational team

As an integrated multisector programme, the GGW monitors and evaluates the operations and activities of different components at various levels, from the ground up to the international level. The transborder restoration project is led collaboratively by the RBG Kew and FAO's Forestry Department, and is managed through three national technical partner institutions, local and national governments in the regions, environmental NGOs, and several other international partners. The team is as inclusive as possible, while minimizing unnecessary complexity, and is composed of a large number of stakeholders to guarantee success on the ground (Figure 1). The in-country technical leadership of the national tree seed centres addresses the availability of good-quality seed collections, ensuring genetic diversity that reflects the original provenances of native species. These collections serve as base material for plant production for the restoration activities. Both local administrations and NGOs contribute to mobilizing communities. A designated national focal point coordinates interventions and a steering committee oversees progress and reports annually on GGW development.

Community consultation and species prioritization

A total of 110 village communities were selected in 2013 and 2014, including 82 in Burkina Faso, 9 in Mali and 19 in the Niger (Table 1). A total of 193 plant species were listed as useful by the 110 communities,

Rainwater harvested on prepared Great Green Wall planting site, Dori, Burkina Faso

© MOCTAR SACANDE

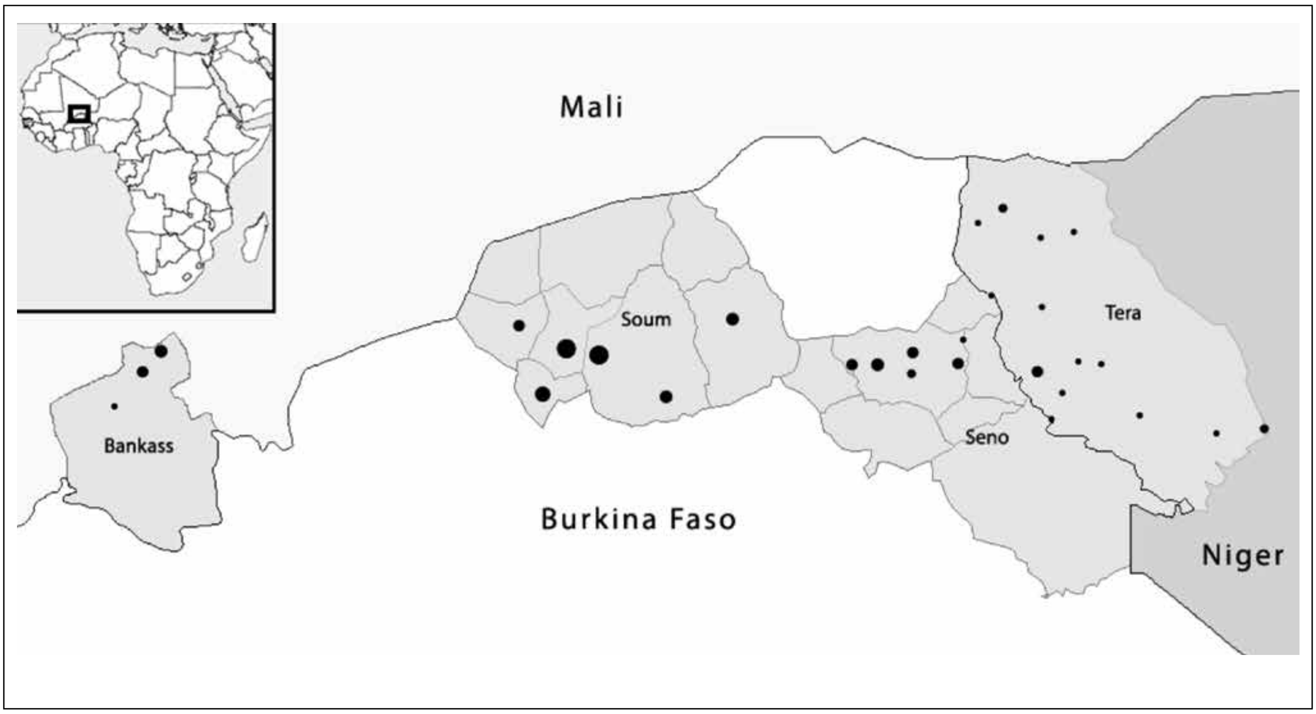
consulted using questionnaires and village workshops. However, the botanical analyses of results showed that only 73 percent of these species were suitable and appropriate for dryland ecosystems. The rest of the list reflected farmers' personal knowledge or aspirations, and included species that were either exotics or suitable for more humid environments. Selected species were usually preferred for their social utility, their importance as food and feed species, and their environmental adaptation to the implementation areas and dryland ecosystems. Plant-use data given by respondents in the communities were classified according to the Economic Botany Data Collection Standard (Cook, 1995). Medicinal use for humans represented the highest share of responses, with 143 species listed (74 percent), followed by 112 for animal feed (58 percent) and 105 for food (54 percent). A detailed implementation timetable was fed back to the communities and agreed on by all stakeholders, including prioritization of species and activities for restoration.

Achievements of the GGW pilot project so far

Beneficiaries of the plantations number just under 50 000 people, including 25 170 women (51 percent). The number of communities has shown a marked increase over the two years of the project, with 89 more villages in 2014 as compared to the initial 21 in 2013. This was due in part to the addition of Djibo during the second year of the project, as well as to the expansion of training programmes across the GGW pilot project area. Farmers participated in locally run training programmes, the first of which took place in Dori, involving national partners and new partners from the Niger and strengthening capacity and collaboration across borders.

TABLE 2. A total of 21 prioritized GGW species were selected by and planted with communities in the four cross-border regions of Burkina Faso, Mali and the Niger in 2013–2014. Of these, 75 percent are woody species, against 25 percent of grasses (4 out of the 21 species), mainly used as feed, fodder and food

	Family	Taxon	Life form	Height (m)	Main uses	Seed collection (month)	1000-seed weight (g)	Average germination (%)	Planted form
1	Leguminosae	*Acacia nilotica*	Shrub	4.0	Gum, fodder	1	140.00	100	seedlings
2	Leguminosae	*Acacia senegal*	Shrub	4.0	Gum arabic, bees, forage	3	100.00	100	seeds & seedlings
3	Leguminosae	*Acacia seyal*	Tree	4.0	Gum, fodder	3	42.69	95	seedlings
4	Leguminosae	*Acacia tortilis*	Shrub	4.0	Gum, fodder	4	26.44	100	seedlings
5	Bombacaceae	*Adansonia digitata*	Tree	10.0	Food, medicine	3	399.30	80	seedlings
6	Leguminosae	*Alysicarpus ovalifolius*	Grass	0.5	Feed, fodder	10	2.50	60	seeds (10 kg/ha)
7	Poaceae	*Andropogon gayanus*	Grass	2.5	Roofing, forage	11	2.50	100	seeds (5 kg/ha)
8	Balanitaceae	*Balanites aegyptiaca*	Tree	6.0	Food, oils, medicine, fodder	1	3 000.00	100	seedlings
9	Leguminosae	*Bauhinia rufescens*	Shrub	3.0	Fodder, fence, rope	10	78.63	100	seedlings
10	Combretaceae	*Combretum micranthum*	Shrub	3.0	Fodder, food, medicine	12	28.66	100	seedlings
11	Poaceae	*Cymbopogon giganteus*	Grass	2.0	Medicine, beverage, pesticide	12	1.44	56	seeds (5 kg/ha)
12	Leguminosae	*Faidherbia albida*	Tree	15.0	Fodder, medicine, wood	3	51.60	100	seedlings
13	Arecaceae	*Hyphaene thebaica*	Palm-tree	12.0	Wood, food, fodder	11	24 000.00	100	seedlings
14	Meliaceae	*Khaya senegalensis*	Tree	15.0	Wood, medicine, pesticide, fodder	2	260.00	100	seedlings
15	Anacardiaceae	*Lannea microcarpa*	Tree	6.0	Food, rope	7	200.00	80	seedlings
16	Poaceae	*Panicum laetum*	Grass	0.1	Food, feed	11	1.10	20	seeds (5 kg/ha)
17	Leguminosae	*Parkia biglobosa*	Tree	8.0	Food, medicine, bees	4	1 000.00	100	seedlings
18	Poaceae	*Pennisetum pedicellatum*	Grass	2.0	Fodder	11	0.98	100	seeds (0.5 kg/ha)
19	Leguminosae	*Prosopis africana*	Tree	7.0	Food, medicine, wood	2	106.20	100	seedlings
20	Leguminosae	*Tamarindus indica*	Tree	10.0	Food, medicine	3	385.00	100	seedlings
21	Rhamnaceae	*Ziziphus mauritiana*	Shrub	2.0	Food, fence, medicine	11	382.80	87	seedlings



2
The 86 out of 110 georeferenced villages participating in and benefiting from the GGW pilot restoration project, across the four transborder regions of Bankass (Mopti region), Mali; Djibo (Soum province) and Dori (Seno province), Burkina Faso; and Tera (Tillabery region), the Niger. The size of the black circles is relative to the number of villages, with the biggest circles in Soum (Djibo) representing groups of 10–12 villages

Quality seed collections and seedling production of woody species in selected village nurseries, with training in local administrative nurseries, were initiated. Over 1 million seeds and seedlings were produced and planted in the four trans-border regions. Within the plantation areas, over 500 000 seedlings were planted over the two years of the project, following traditional local practices and the agroforestry planting design of farmers in the Sahel. Seeds of mostly herbaceous species were sown directly (Table 2). Data collected on planting and field performance and technical reporting were incorporated into national GGW plans.

Village communities involved in the planting of their land participate in the regular monitoring and evaluation of the plots. Ninety village technicians have been trained and mentored in the collection of seeds and production of seedlings in village nurseries near the planting sites. In its first year, the project reached about 70 administrative technicians who were familiarized with the restoration model and committed to contributing to the activities on the ground.

DISCUSSION

The intrinsic and complex link between people and the landscapes in which they live is of critical importance when developing a restoration programme. Projects that aspire to address both poverty and conservation issues face a complex challenge (Turner *et al*., 2012; McShane *et al*., 2011). With humans continuing to be the main driving force in dryland ecosystems (Aronson *et al*., 1993), incorporating the needs of local communities and other stakeholders is vital both to achieve environmental goals and to promote human well-being.

The long-term success of these restoration actions lies in the return on investment, for both the environment and people's food security and livelihoods. High poverty and a high demand for food, feed and fuelwood, leading to high depletion rates of and pressure on natural forest resources, severely affect the Sahel region (OECD/SWAC, 2014). Combining the planting of slow-growing native woody plants with fast-growing native edible herbaceous and fodder species for livestock has been a great success and is in high demand in other neighbouring communities. The restoration model also took into account open pastureland for animals, which is crucial for most of the pastoralist communities of the Sahel. As suggested by Weber and Horst (2011), inclusive planning processes may improve arid and semiarid rangeland ecosystems, incorporating livestock into solutions to the problem of land degradation. Benefits are already being seen in the harvesting of edible grass seeds and the collecting of fodder from the planted plots.

A recent renewal of interest in the GGW reflects concerns over desertification and loss of biodiversity in the context of climate change, and the implications for food security. The programme itself is currently being implemented in a piecemeal fashion,

© MOCTAR SACANDE

Land cover with planted grass species in Tera, the Niger

© MOCTAR SACANDE

Planted seeds and seedlings in Great Green Wall site in Tera, the Niger depending on countries' priorities and the mobilization of funds. For example, there has been major land restoration in Senegal and the Niger through the programme (FAO, 2015), whereas in Burkina Faso and Mali the current pilot project represents the very first restoration action on the ground, with work in other GGW countries yet to begin.

An essential aspect of the GGW programme is to ensure local involvement and community ownership of the restoration investments. For this reason, the model approach is based on the consultation and involvement of local communities and villages. Within the communities there is buy-in and strong support for this restoration programme. However, assessments and management interventions must be completed at the local level to ensure that success is sustainable. This requires the inclusion of local people at every step in the process.

CONCLUSIONS

The GGW has mobilized and engaged communities, with over 110 villages in four cross-border regions of Burkina Faso, Mali and the Niger already engaged. While this major international project is gaining momentum, it is important to note that the communities in these areas have always demonstrated resilience and perseverance in improving their environment and have reaped the benefits of their investments in these lands. It is time to provide them with serious support.

Acknowledgements

We thank in particular the village communities, the Millennium Seed Bank teams and The Dr Mortimer and Theresa Sackler Foundation, who support the Royal Botanic Gardens, Kew, and Africa's Great Green Wall pilot restoration model project in Burkina Faso, Mali and the Niger. ◆

References

Aronson, J., Floret, C., LeFloc'h, E., Ovalle, C. & Pontanier, R. 1993. Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. Vol. I. A view from the South. *Restoration Ecology*, 1: 8–17.

AUC/PAGGW (African Union Commission/ Pan African Agency of the Great Green Wall). 2012. *Harmonized regional strategy for the implementation of the Great Green Wall for the Sahara and the Sahel Initiative* (available at: http://www.fao.org/fileadmin/templates/europeanunion/pdf/harmonized_strategy_GGWSSI-EN_.pdf).

Berrahmouni, N., Tapsoba, F., Berte, J.C. 2014. The Great Green Wall for the Sahara and the Sahel Initiative: building resilient landscapes in African drylands. *In* M. Bozzano, R. Jalonen, E. Thomas, D. Boshier, L. Gallo, S. Cavers, S. Bordács, P. Smith & J. Loo, eds. *Genetic considerations in ecosystem restoration using native tree species*. State of the World's Forest Genetic Resources Thematic Study. Rome, FAO and Bioversity International.

Bremner, J., Lopez-Carr, D., Suter, L., Davis, J. 2010. Population, poverty, environment, and climate dynamics in the developing world. *Interdisciplinary Environmental Review*, 11: 112–26.

Cook, F.E.M. 1995. Economic Botany Data Collection Standard. Royal Botanic Gardens, Kew (available at http://www.cabdirect.org/abstracts/19950316220.html).

FAO. 2015. *Africa's Great Green Wall reaches out to new partners* (available at http://www.fao.org/news/story/en/item/210852/icode/).

Fingar, C.T. ed. 2008. *Global trends 2025: a transformed world*. Washington, DC, US Government Printing Office (available at http://news.bbc.co.uk/1/shared/bsp/hi/pdfs/21_11_08_2025_Global_Trends_Final_Report.pdf).

IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate change 2014: impacts, adaptation, and vulnerability*. Cambridge, United Kingdom, Cambridge University Press.

McShane, T.O., Hirsch, P.D., Trung, T.C., Songorwa, A.N., Kinzig, A., Monteferri, B., Mutekanga, D., Thang, Hv., Dammert, J.L., Pulgar-Vidal, M., Welch-Devine, M., Brosius, J.P., Coppolillo, P. & O'Connor, S. 2011. Hard choices: making trade-offs between biodiversity conservation and human well-being. *Biological Conservation – The New Conservation Debate: Beyond Parks vs. People*, 144: 966–72.

Nakhooda, S., Caravani, A., Bird N. & Schalatek L. 2011. *Climate finance fundamentals: regional briefing: Sub-Saharan Africa*. Heinrich Böll Stiftung North America and Overseas Development Institute (available at http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/7474.pdf).

OECD/SWAC (Organisation for Economic Co-operation and Development/Sahel and West Africa Club). 2014. *An atlas of the Sahara-Sahel: geography, economy and security*. West Africa Studies. Paris, OECD Publishing.

Turner, W.R., Brandon, K., Brooks, T.M., Gascon, C., Gibbs, H.K., Lawrence, K.S., Mittermeier, R.A. & Selig, E.R. 2012. Global biodiversity conservation and the alleviation of poverty. *BioScience*, 62: 85–92.

Weber, T.K. & Horst, S. 2011. Desertification and livestock grazing: the roles of sedentarization, mobility and rest. *Pastoralism: Research, Policy and Practice*, 1(1): 1–11. ◆

Restoration of forests and degraded lands in Southeast Asia[1]

S. Appanah, K. Shono and P.B. Durst

© FAO/NOEL CELIS

Above: People clear brush and define a fire line to protect an area from forest fires in Danao, the Philippines

Forest restoration programmes in the region are unlikely to succeed without policy reform and the participation of local people.

Simmathiri Appanah is former Forestry Officer (retired) of the FAO Regional Office for Asia and the Pacific.
Kenichi Shono is Forest Resources Officer with the FAO Regional Office for Asia and the Pacific.
Patrick B. Durst is Senior Forestry Officer with the FAO Regional Office for Asia and the Pacific.

The Southeast Asia region has given rise to some of the best scientific innovations in the history of tropical forestry, such as the *taungya* system of agroforestry and the introduction of teak to Java, where it became naturalized and a major contributor to the local economy. Yet, in an ironic twist, this region now requires massive investments to restore its degraded forests and lands.

Extending from Myanmar in the west to the Indonesian islands in the east, Southeast Asia contains the world's third largest concentration of tropical forests (FAO, 2010). The forests in continental Southeast Asia are mainly of the mixed deciduous types, including the valuable teak forests. The insular subregion holds extensive areas of the highly productive evergreen dipterocarp forests. The region also has extensive areas of montane, mangrove and peat swamp forests.

These forests are regarded as the oldest existing tropical ecosystems, known for very high biodiversity (MacKinnon *et al*., 1996); some 14–34 million indigenous

[1] This article draws extensively on a larger review of forest landscape restoration undertaken for the Asia-Pacific region (Appanah and Leslie, in press).

Degraded forest landscape in the Philippines

© K. SHONO

people depend on them for their livelihoods (Mertz *et al.*, 2009). The prevailing highly humid conditions in the region have given rise to exceptionally productive forests, including a large stocking of commercially valuable timber trees. This wealth of timber trees has ironically become a challenge to the very survival of the region's forests. Following the post-colonial era, the timber industry grew rapidly in the region, and exports of hardwoods such as teak and Philippine mahogany[2] took off. By 2011, the region's forestry sector provided, on a formal basis, employment for about 1.25 million people, and generated about US$27.4 billion in value added (FAO, 2014). In addition, these forests are also the largest source of land for massive plantations of export-oriented cash crops such as rubber, oil palm and cocoa. For example, both Indonesia and Malaysia currently have about 10 million ha under oil palm, which earn about US$30 billion annually.

In the process of pushing for economic growth based on forestry and forest conversion for agriculture, extensive deforestation and degradation of forests and lands have taken place in the region. Many reviews have been produced on the drivers of deforestation and degradation (e.g. Geist and Lambin, 2002; De Jong, 2005). While the drivers are usually distinguished according to proximate (direct) and underlying (indirect) causes, the results usually derive from their interactions.

In the region, agricultural expansion that includes establishment of permanent crops (especially cash crop plantations), shifting cultivation and resettlement of populations has been a major cause of deforestation and degradation (Butler, 2009; FAO, 2009). This expansion in agriculture and increased demand for forest goods stems from economic development and increasing purchasing power across broad segments of society. When this is coupled with population growth, deforestation is amplified further. Expansion of biofuel production has placed additional pressure on forests. Likewise, hydropower development has resulted in extensive loss of forests. This high level of deforestation is underwritten by policies that provide strong incentives for agricultural growth, transportation and infrastructure development.

Inappropriate land-use policies combined with transmigration policies, for example in Indonesia, have led to the opening of forests for settlements. In the process, lands unsuitable for agriculture were opened and subsequently abandoned when agricultural initiatives failed. Further exacerbating the problems was the lack of recognition of the rights of local communities to their traditional use and access to forest resources. Without appropriate tenure in place and improved agricultural productivity, landless farmers have continued to encroach upon state forest reserves.

Logging in itself rarely results in deforestation directly, but bad logging practices have led to extensive forest degradation. While methodologies to ensure good logging practices are available (e.g. regional and national codes of harvesting [FAO, 1999]), they may not be implemented effectively and regulations designed to ensure sustainability are often poorly enforced. The resulting degraded forests then become increasingly vulnerable to encroachment, fire, pests and diseases.

---

[2] The name "Philippine mahogany" is used to refer to a number of commercial timber species in the *Shorea* genus. Other common names for this wood are "Meranti" and "Lauan".

TABLE 1. Extent of forest land (2015) and trends in forest change (1990–2015)

Country	Forest area 2015		Annual change rate							
			1990–2000		2000–2005		2005–2010		2010–2015	
	1 000 ha	% of land area	1 000 ha/yr	%	1 000 ha/yr	%	1 000 ha/yr	%	1 000 ha/yr	%
Brunei Darussalam	380	72.1	-1.6	-0.4	-1.7	-0.4	0	0	-1.3	-0.3
Cambodia	9 457	53.6	-139.8	-1.1	-145.2	-1.3	-127.4	-1.3	-139.5	-1.2
Indonesia	91 010	53.0	-1 913.6	-1.7	-497.7	-0.5	-684.4	-0.7	-1 101.4	-1.1
Lao People's Democratic Republic	18 761	81.3	-111.9	-0.7	129.0	0.8	189.2	1.0	44.7	0.2
Malaysia	22 195	67.6	-78.5	-0.4	53.3	0.2	14.2	0.1	-7.2	0
Myanmar	29 041	44.2	-435.0	-1.2	-309.5	-0.9	-546.4	-1.8	-407.1	-1.2
Philippines	8 040	27.0	47.2	0.7	-18.7	-0.3	240.0	3.3	59.4	0.8
Singapore	16	23.4	0	0	0	0	0	0	0	0
Thailand	16 399	32.1	300.6	2.0	-76.2	-0.5	30.0	0.2	95.8	0.6
Timor-Leste	686	46.1	-11.2	-1.2	-11.2	-1.4	-11.2	-1.6	-11.2	-1.4
Viet Nam	14 773	47.6	236.4	2.3	240.1	1.9	129.0	0.9	216.4	1.8
Total	**210 758**	**-**	**-2 107.4**	**-0.1**	**-637.8**	**-0.1**	**-767.0**	**-0.1**	**-1 251.4**	**-0.1**

Source: FAO, 2015.

A case in point is the current increase in forest fires, which were previously rare in the natural forests of Southeast Asia (Wooster *et al*., 2012). Many other policies and regulations, including low stumpage fees and taxes on forest concessions, and inadequate investment in forest management have resulted in poor forest management and subsequent conversion of forest to other land uses. Overall, the situation in Southeast Asia is a result of rapid economic growth that has frequently taken place at the expense of environmental and biodiversity concerns. This brings us to the crux of the issue: How much degraded forest and land exists that can be restored? What experiences can be drawn upon to guide such initiatives?

EXTENT OF DEGRADED FORESTS AND LANDS

In the early 1990s, Southeast Asia had about 15 percent of the world's tropical forests (FAO, 1995). The forest cover declined from around 242 million ha in 1990 to around 211 million ha in 2015 (Table 1). This represents a loss of 31 million ha, an area comparable to the size of Malaysia, in only 25 years. The only positive trends come from the Lao People's Democratic Republic, the Philippines, Thailand and Viet Nam, with increases in forest cover. Additional perspective is gained when this annual loss in Southeast Asia of over 1.25 million ha is compared with the global annual loss of about 5.17 million ha (FAO, 2015).

But for the purposes of restoration, it would be more useful to estimate how much degraded forest and deforested and abandoned areas exist and are potentially available for restoration. While deforestation is relatively easy to estimate, the extent of forest degradation is more difficult to quantify. Achard *et al*. (2002) have estimated that in the 1990s, the annual rate of forest degradation in Southeast Asia was as high as 1.1 million ha, or about half the global figure (Table 2).

Considering that deforested areas converted to other land uses are often not available for forestry, it is important to consider the extent of degraded forests and degraded lands that are actually available for forest restoration. ITTO (2002) estimated that there were 125 million ha of degraded forest land and 145 million ha of degraded primary and secondary forests in tropical Asia. Table 3 shows estimates for Southeast Asia in terms of the total area of degraded lands (grasslands, shrublands, and degraded secondary forests) and areas the countries have identified for restoration (Lamb, 2011). The percentages of degraded land and forest area vary considerably among the countries (figures of 4 percent for Malaysia and Thailand appear to be

TABLE 2. Annual changes in forest cover in the tropics (evergreen and seasonal forests, but not dry tropical forests) between 1990 and 1997

Activity	Southeast Asia		Global	
	Million ha	%	Million ha	%
Deforestation	2.5	0.91	0.52	-0.4
Regrowth	0.53	0.19	0.08	-1.1
Net forest loss	2.0	0.71	0.43	-1.7
Degraded forest	1.1	0.42	0.20	-0.1

Source: Achard *et al*., 2002.

TABLE 3. Estimates of areas of degraded lands in some Southeast Asian countries (grasslands, shrublands and some secondary forests) and of land potentially available for reforestation (compilation of data from 1994 to 2007)

Country	Area of degraded land ('000 ha)	Percent of land area	Areas planned to be reforested ('000 ha)
Cambodia	2 600	15	-
Indonesia	56 900	30	47 000
Lao People's Democratic Republic	8 700	36	-
Malaysia	1 200	4	-
Philippines	9 300	31	5 500
Thailand	2 300	4	-
Viet Nam	9 700	30	5 000

Source: Lamb, 2011.

underestimated) and may not necessarily reflect the reality on the ground. Others have cited higher figures of as much as 169 million ha of degraded forests and lands for Southeast Asia (Gilmour *et al*., 2000) and 400 million ha of southern and eastern Asia's deforested and degraded landscapes as potentially available for restoration (WRI, 2013). Needless to say, by any of these estimates, there are very large areas potentially available for restoration.

APPROACHES IN FOREST RESTORATION – TECHNICAL SOLUTIONS

From the standpoint of environmental protection, biodiversity and economic benefits, the best option would be to restore the region's vast degraded forests and lands to some level of productivity. As alluded to in the introduction, restoration practices are not new to forestry in Southeast Asia. In Java, teak, which was probably introduced 400–600 years ago, has become naturalized (Troup, 1921, pp. 697–769), and is now grown in plantations and agroforests. The *taungya* system for reforesting shifting cultivation areas with teak was first introduced in Burma (now Myanmar) by Dietrich Brandis in 1856, and is frequently associated with the beginnings of scientific forestry in the tropics (Blanford, 1958). The system has been widely used in Southeast Asia (Appanah and Weinland, 1993). Since these early beginnings, a variety of restoration techniques have been developed and tested, which will be discussed later.

The starting point would be: What is it we want to restore, what are the techniques available for restoration, and what policies are needed to facilitate restoration? A broad classification of degraded forests based on the underlying disturbances and past land-use practices (Chokkalingam and De Jong, 2001) includes the following: secondary forests following natural catastrophes or tree harvesting, swidden agriculture, abandoned secondary forests not intended for forestry, and degraded lands that are completely barren or under *Imperata* grass.

A variety of techniques are available for forest restoration, including natural regeneration, monoculture plantations and mixed-species plantations. The last includes agroforestry, uneven-aged tree plantations, even-aged plantations with short- or long-rotation species, planting of mixtures of species for restoring native forest ecosystems ("framework species" [Eliott *et al*., 2013]) and mosaics of monocultures. Lamb (2011) provides a full review of the various restoration techniques. These techniques fit the various needs and objectives of the range of forest owners, from smallholders to industrial plantations, and cover a wide spectrum in terms of costs and benefits provided.

To improve the timber stocking of degraded natural forests, the most commonly used approach is enrichment planting (either gap or line planting), in which seedlings of desirable species are planted as part of the silvicultural management of the stand. However, the most common approach to forest restoration involves the establishment of commercial tree plantations (Lamb, 2011). Both monocultures and mixed-species plantations have been established in Southeast Asia. Despite the advantages that mixed-species plantations provide in terms of greater biodiversity, enhanced watershed protection and more carbon storage (Kanowski *et al*., 2005; Zhou *et al*., 2002; Russell *et al*., 2004), monocultures of exotic timber species continue to be favoured in commercial plantations for their well-known silvicultural characteristics and productivity (FAO, 2001). Although profit-oriented by nature, large industrial plantations can provide varying degrees of socioeconomic benefits to local communities in the form of employment and business opportunities.

Various ecological restoration methods involving the planting of mostly native tree seedlings have been developed to reforest degraded lands (Lamb *et al*., 2005). Some of these methods aim to recreate an ecosystem that is as close as possible to the original one, while others strive to establish a functionally effective and self-sustaining system with as many of the original species as practically achievable. Dense to staggered planting of native tree species in various planting designs, including the framework species method and "rainforestation" approach, have been implemented with promising results (e.g. Goosem and Tucker, 1995; FORRU, 2005; Shono *et al*., 2007; RFRI, 2015). The considerable financial inputs, which could range from US$2,000 to over US$11,000 per ha depending on site conditions and circumstances (Elliot, 2011), associated with their complex methods, limit their application to relatively small-scale projects (Lamb, 1998).

A simple and cost-effective restoration approach that captures the natural recovery potential of forest ecosystems is the assisted natural regeneration (ANR) method, pioneered in the Philippines in the 1980s (Dalmacio, 1989; FAO, 2011a). ANR accelerates succession, converting areas of degraded vegetation to more productive forests by removing or reducing barriers to natural forest regeneration (e.g. weed competition, fire and other recurring disturbances). The cost of forest restoration through ANR is typically less than half that of conventional reforestation approaches (Bagong Pagasa Foundation, 2009). Agroforestry is also gaining importance as another restoration technique and climate change adaption strategy that is more relevant to farmers with small landholdings (Winterbottom, 2014). At the same time as it introduces the benefits of forests (e.g. ecosystem services and useful products) into farmland, the integration of agricultural crops and trees also ensures that farmers need not forego short-term income generation.

Degraded forest land after grass pressing as part of the assisted natural regeneration method of forest restoration in the Philippines

© K. SHONO

Country case studies

Countries in Southeast Asia have had varied experience in forest restoration, depending on economic development paths, governance regimes, social context, biophysical conditions and other factors that have shaped the pattern of forest resource use. Almost all countries have experienced heavy deforestation. Some are still experiencing such losses, while others have succeeded in reversing forest loss. Past gains have relied predominantly on the establishment of monoculture plantations of exotic species. However, many countries are beginning to recognize the importance of accommodating broader objectives in forest restoration at the landscape level. These country experiences, and the range of technical approaches used, are briefly summarized in this section.

Indonesia

While Indonesia still enjoys relatively high forest cover (53 percent), it continues to face heavy forest degradation and forest loss from conversion to other uses, mainly for agriculture, including oil palm. While people traditionally depended heavily on forests for their livelihoods, this option has become less viable with policies centred on land conversion for cash crops and timber production. During the last 50 years, there have been 150 official rehabilitation projects in 400 locations nationwide (Nawir *et al.*, in press). Technical approaches include the establishment of industrial plantations of fast-growing exotic species, community forestry, planting of high-value timber species on private lands, agroforestry, enrichment planting with native species and ANR. However, the results of these reforestation efforts have largely been unsatisfactory due to lack of local community participation, tenure issues, ineffective private-sector involvement, premature decentralization, and other problems. The government has taken steps to renew the role of people's participation in forest restoration. New approaches include the establishment of regional forest management areas, within which forest utilization, rehabilitation and empowerment of local communities are implemented in an integrated manner. This raises the potential for restoring vast areas of degraded lands with a landscape approach.

Malaysia

While Malaysia has managed to retain a high level of forest cover and relatively good management of natural forests, the challenges of rehabilitating degraded forests and restoring waste lands (ex-mining land, abandoned agricultural land) have also received considerable attention from the early days of state-managed forestry. As far back as 1900, there has been concern about the loss of desired species due to overharvesting of commercial species (e.g. *Palaquium gutta* for gutta percha,[3] and *Intsia palembanica* and *Neobalanocarpus heimii* – heavy hardwoods for railway sleepers). Wildings of these desirable species were raised in plantations and in-line plantings in degraded forests. Also in the early twentieth century, afforestation of ex-mining land with both indigenous and exotic species was carried out (Wyatt-Smith, 1963). These early experiences became the basis for managing degraded forests and waste lands. Line planting (later called enrichment planting) became an important silvicultural procedure in natural forest management. In the mid-1950s, large trials of teak (*Tectona grandis*) were introduced in the northern states of peninsular Malaysia. In the 1970s, compensatory plantations, mainly with exotics such as *Acacia* and *Gmelina*, were introduced to meet the reduction in timber output from natural forests. The State of Sabah introduced 100-year Sustainable Forest Management concessions in 1997, which requires restoration of degraded sites as part of the permit (Toh and Grace, 2005). The state has also implemented large restoration and rehabilitation projects in cooperation with the FACE Foundation of the Netherlands and others (Reynolds *et al*., 2011). In addition, the States of Sabah and Sarawak have started large plantation programmes with a mixture of indigenous and exotic species. Despite these extensive trials and research into restoration work, the lack of appropriate policies, incentives and involvement of communities has held back attempts to restore degraded forests and lands and increase forest cover in the country.

[3] Used as insulation material for the earliest undersea telegraphic cables.

© FAO/FLORITA BOTTS

A young man plants* Eucalyptus *trees to fight erosion in the Upper Solo River basin, Indonesia

Myanmar

While Myanmar has a rich history in forest management, it is mainly focused on natural forests. Forest plantations have remained marginal, and community forestry has not been fully implemented. Myanmar's main efforts to restore forest cover have been with the establishment of commercial plantations of native species (teak, *Xylia*, *Pterocarpus*, pine, etc.), industrial plantations of fast-growing exotic species, watershed restoration, and plantations for meeting local wood demand, mainly for fuelwood. The *taungya* system, which incorporates annual agricultural crops during the early years of forest plantation establishment, is still widely used for rehabilitating degraded lands. In addition, enrichment planting is done after harvesting in natural forests. Rehabilitation of degraded natural forests is also recognized as an effective and cost-efficient strategy to restore degraded forests. However, with a minimal budget of US$6 per ha, positive impacts of such efforts have been slow to emerge (Kaung, in press). While there is a huge need for stepping up forest restoration, the basic requirements of appropriate policies, institutional set-ups and technical knowledge have yet to be met.

The Philippines

The Philippines experienced high rates of deforestation from the 1970s, with its forest cover declining to 20 percent in 1990. A variety of reforestation techniques have been introduced, including plantations of fast-growing exotic species, enrichment planting in understocked forests, restoration with indigenous tree species, ANR and agroforestry. However, these efforts have been hampered by inadequate protection and maintenance in the past. In 2011, the Philippines Government launched the National Greening Program, which aims to grow 1.5 billion trees over 1.5 million ha nationwide by 2016. The programme strategy includes components relating to social mobilization, agroforestry, partnerships and collaboration, poverty reduction, and tenure and use rights. Half of the trees to be planted under the programme are native forest tree species, while agroforestry species comprise the other half. The programme has benefited from a sizeable national budget, which in 2013 reached 5.8 billion Philippine Pesos (approximately US$130 million) (DENR, 2015). As a result of this programme, forest loss has been stemmed and forest cover has slowly begun to increase (FAO, 2010).

Thailand

After experiencing rapid deforestation as a result of encroachment, illegal logging, fire and other causes, a logging ban on natural forests was imposed in 1989. Forest restoration approaches in Thailand have evolved over time. Native timber species were planted in the early days (mainly teak, *Pterocarpus*, *Dalbergia*) to compensate for the decline in productivity of natural forests. In the 1970s, pines and acacias were used to protect degraded watersheds, while exotic fast-growing species (*Eucalyptus*, *Acacia*, *Peltophorum*) were used to reclaim encroached forest reserves. Since the 1980s, large private companies have developed eucalypt plantations for pulp. Although rubber was introduced much earlier, parawood became an important raw material for furniture manufacturing in the 1990s, and the Department of Agriculture expanded the planting of rubber trees. Since the 1990s, besides the Royal Forest Department and the Forest Industry Organization, the private sector and farmers have been involved in forest restoration; through afforestation, restoration of forest concessions and social forestry programmes, the area of forest plantations has expanded to 3.986 million ha.

Viet Nam

By the 1990s, forest cover in Viet Nam had declined to 27 percent, from overharvesting, shifting cultivation, encroachment and damage from war. This was mainly reversed through two large restoration programmes in the 1990s (Program 327 and the Five Million Hectares Reforestation Program).

© K. SHONO

Native tree seedlings ready for field planting in Thailand

Degraded forest land replanted by local communities in Thailand

Together, this resulted in an increase of 4.4 million ha of forest, including the addition of 2.5 million ha of plantations of mainly fast-growing exotic species. As a result, Viet Nam's forest cover increased to 44 percent in 2010 (FAO, 2010). These were mainly monoculture plantations of exotic species, initiated by government agencies with donor support. They also created employment for rural populations and subsequently increased their incomes from forests. Reforestation by private landowners also occurred spontaneously without external support as a result of clarification of tenure and an easing of the regulatory framework for growing and marketing timber. Technical approaches to forest restoration in Viet Nam can be categorized into two groups: reforestation/afforestation through the establishment of forest plantations (the predominant approach); and restoration of natural forests through forest zoning for protection, promotion of natural regeneration and enrichment planting. As Viet Nam approaches its target of 45 percent forest cover, the need to further enhance forest ecosystem services is being increasingly recognized. In this context, the government is now examining approaches to increase the value of natural forests through payments for ecosystem services (PES), focusing mainly on watershed services and carbon sequestration but also including biodiversity and genetic conservation.

FOREST RESTORATION – SUCCESSES AND ENABLING CONDITIONS

Although there is a long history of forest restoration and a broad range of experiences, successes measured on a national scale are few. Indonesia's teak plantations using the *taungya* system are exemplary. Larger monoculture plantations of fast-growing exotics (mainly *Acacia*, *Eucalyptus* and *Gmelina* spp.) have been raised throughout Southeast Asia, mainly for pulp, fuelwood and low-cost lumber. Parawood, an end product of old rubber plantations, has become an important source of timber for the furniture industries in Malaysia, Thailand and Viet Nam. But the region's restoration efforts are dotted with more failures than successes. The outstanding exception is Viet Nam, which has proved capable of restoring its forest cover considerably through its large forest restoration programmes.

This brings us to the key question of the enabling conditions for success. Restoration costs money, and it is useful to look at what these costs are (Enters and Durst, 2004). Forest restoration costs have been difficult to estimate, as they depend on methods, locations and other factors. One generalization is that the costs of restoration will be determined by the stage of degradation, where the costs of protection are relatively low but the costs of complete site amelioration and planting are much higher. Table 4, compiled from various sources indicates that costs vary from US$300 to US$8 890, depending on the stage of degradation. To a large extent, costs and available budget will dictate the kind of restoration work that is possible. Hence, the private sector has focused mainly on pure plantations of fast-growing species. However, efforts that include restoration of environmental services require more innovative financing. Currently, approaches to the financing of forestry-related climate change mitigation, including voluntary carbon markets, REDD+ and PES are receiving enormous attention and there are considerable expectations that such means can provide the funds necessary to accelerate forest restoration. Through a combination of approaches, it should be possible to keep costs at manageable levels and still restore extensive areas of degraded forest and barren lands.

With the build-up of global concern over climate change, interest in reforestation and the reduction of deforestation is rising; restoration approaches can also support various international agreements such as the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol's Clean Development Mechanism (CDM) and the United Nations Convention to Combat Desertification (UNCCD). This has led to the formation of the Global Partnership on Forest and Landscape Restoration (GPFLR), a partnership to catalyse forest restoration, followed by pledges from several countries. These include the Bonn Challenge to restore 150 million ha of deforested and degraded lands, and the Asia-Pacific Economic Cooperation (APEC) pledge to boost forest cover in APEC countries by 20 million ha by 2020. National tree planting campaigns such as the Philippine's National Greening Program to reforest 1.5 million ha nationwide by 2016 have followed. In addition, there have been research and training initiatives (e.g. FORSPA[4] and FORRU[5]), and regional programmes such as AKECOP,[6] APFNet,[7] GIZ,[8] and JICA,[9] designed to support restoration of degraded forests in Southeast Asia. These programmes and institutions are helping generate the momentum, knowledge and financial resources needed for increasingly larger forest restoration programmes.

TABLE 4. Examples of costs for various restoration approaches

Degradation stage	Method	Country	Date	Present-day costs (US$)
Stage 1	Protection	Thailand	-	300–350
Stage 2	Assisted natural regeneration	Philippines	2006–2009	638–739
Stage 3	Framework species method	Thailand	2006	2 071
Stage 4	Mine site amelioration with maximum diversity	Brazil	1985	8 890

Sources: Based on Eliott *et al.*, 2013 ; Nawir *et al.*, in press.

It is important to address the technical aspects of forest restoration in order to avoid major failures. However, a recent review of forest restoration in Asia and the Pacific (Appanah, in press) points out that technical issues are often secondary to questions regarding policies, institutions and social issues. Policies relating to tenure and equity are often unfavourable, restrictive and lacking incentives for communities to undertake forest restoration. They also often fail to facilitate effective participatory decision-making and stakeholder involvement. Viet Nam's extensive restoration programme was only possible with supportive policies that provided clarity on forest and land-tenure issues and encouraged people's participation in the programmes. Countries that are embarking on community forestry are beginning to show stability or an increase in forest cover. The shift from state-controlled forest management towards people's participation, with a strong emphasis on reducing poverty, may provide the means to increase restoration efforts in the region. This can be further strengthened by reducing many of the regulations constraining local forest producers, such as barriers to the growing, cutting and marketing of timber. Removing such barriers could also encourage the private sector to invest in forestry as a long-term business venture (FAO, 2011b; FAO, 2012). By the same token, improving governance would help eradicate informal payments or extortion and thereby improve the profitability of tree growing. Furthermore, policy and legislative changes outside the forestry sector, such as land-use classification and the provision of preferential credits, have shown positive impacts on forest restoration work.

Besides supportive policies, other lessons that can be drawn from successes in the region include some of the following:

- *National-level support:* Many successful forest restoration efforts are carried out as part of country-wide initiatives

[4] FAO's Forestry Research Support Programme for Asia-Pacific.

[5] Forest Restoration Research Unit, Chiang Mai University, Thailand.

[6] ASEAN-Korea Environmental Cooperation Project.

[7] Asia-Pacific Network for Sustainable Forest Management and Rehabilitation.

[8] The German international cooperation agency.

[9] Japan International Cooperation Agency.

with strong political backing, funding support and effective monitoring that regularly reviews results and realigns efforts according to objective feedback. This is best implemented under timeframes of c. 10–20 years, so that meaningful results can be demonstrated in a practical manner. It was such a vision and long-term commitment that yielded successful recovery results in Viet Nam as well as the recent reversal of forest loss trends in the Philippines resulting from the National Greening Program.

- *Institutions:* One of the biggest obstacles appears to be a rigid state control of forests, which limits the role of communities and the private sector. Where government institutions demonstrate flexibility and adapt to the changing environment and stakeholders' needs, successes are more likely (FAO, 2008). Viet Nam, and now Indonesia and the the Philippines are making such positive changes.
- *Support from other sectors:* Recognizing the important impacts that other sectors (e.g. agriculture, energy, transportation and urban development) have on forests, it is essential to ensure that their deleterious effect on forests is minimized and mitigated.
- *Diversity of forest services:* Instead of a narrow focus on forests as a source of wood, successful restoration efforts recognize the diverse values of forests, including the full range of environmental services. Diversification can be strengthened by attributing value to them, including through the development of PES.
- *Community participation:* The one single factor that has brought tremendous change and benefits with respect to forest restoration is the effective involvement of local people in restoration programmes. Viet Nam has already demonstrated this, and other countries such as Indonesia and the Philippines are following, to increase people's participation in forest management.

Currently, a landscape approach to forest restoration is increasingly being promoted in Southeast Asia (e.g. Mansourian *et al*., 2005; Lamb, 2011; Appanah and Leslie, in press). The Forest and Landscape Restoration (FLR) Mechanism, launched by FAO in mid-2014, attempts to integrate forest restoration actions with desirable landscape-level objectives undertaken in a participatory manner by all stakeholders, and bring about a balance between conservation and production (McGuire, 2014). In effect, the FLR approach captures all the factors identified above, which form the basis for the success of restoration.

© K. SHONO

Primary peat swamp forest in Brunei Darussalam

CONCLUSIONS

Southeast Asia's tropical forests are unique ecosystems that are immensely valuable for maintaining the global environment, and have provided valuable livelihoods for millions of its people over the millennia. Over-exploitation and poor management have resulted in huge tracts of degraded forests and lands in the region. The reversal of this degradation through restoration of the forests and lands can bring numerous benefits, measured in enhanced environmental services and forest goods. The techniques for restoring these forests are numerous, and have been well tested from a technical perspective. However, changes at the policy, legislative and institutional levels are a prerequisite for the success of all forest restoration programmes in the region. Perhaps the most important key to success is the participation of local people in restoring forests. ◆

References

Achard, F., Eva, H., Stibig, H.J., Mayaux, P., Gallego, J., Richards, T. & Malingreau, J-P. 2002. Determination of deforestation rates of the world's tropical forests. *Science*, 297: 999–1002.

Appanah, S. (in press). Forest landscape restoration for Asia-Pacific forests – a synthesis. *In* Appanah, S. & Leslie, R., eds. *Forest landscape restoration for Asia-Pacific forests*. Bangkok, FAO Regional Office for Asia and the Pacific and RECOFTC.

Appanah, S. & Leslie, R. (eds) (in press). *Forest landscape restoration for Asia-Pacific forests*. Bangkok, FAO Regional Office for Asia and the Pacific and RECOFTC.

Appanah, S. & Weinland, G. 1993. *Planting quality timber trees in Peninsular Malaysia*. Malayan Forest Record No. 338. Kuala Lumpur, Forest Research Institute Malaysia.

Bagong Pagasa Foundation. 2009. *Cost comparison analysis, ANR vs. conventional reforestation*. Paper presented at the concluding seminar of FAO project "Advancing the Application of Assisted Natural Regeneration (ANR) for Effective, Low-Cost Forest Restoration" (TCP/PHI/3010).

Blanford, H.R. 1958. Highlights of one hundred years of forestry in Burma. *Empire Forestry Review*, 37(1): 33–42.

Butler, R.A. 2009. Changing drivers of deforestation provide new opportunities for conservation. *Mongabay* (available at http://news.mongabay.com/2009/12/changing-drivers-of-deforestation-provide-new-opportunities-for-conservation/).

Chokkalingam, U. & De Jong, W. 2001. Secondary forest: a working definition and typology. *International Forestry Review*, 3(1): 19–26.

Dalmacio, M.V. 1989. *Assisted natural regeneration: a strategy for cheap, fast, and effective regeneration of denuded forest lands*. Manuscript prepared by the Philippines Department of Environment and Natural Resources Regional Office, Tacloban City, Philippines (unpublished).

De Jong, W. 2005. Understanding forest landscape dynamics. *In* Restoring forest landscapes: an introduction to the art and science of forest landscape restoration, pp. 53–60. ITTO Technical Series 23. Yokohama, International Tropical Timber Organization.

DENR (Department of Natural Environment Resources). 2015. Website (available at http://www.denr.gov.ph/).

Elliott, S. 2011. *Plotting a pathway towards restoring tropical forests for biodiversity recovery*. Chiang Mai, Thailand, Forest Restoration Research Unit (FORRU), Chiang Mai University.

Eliott, S.D., Blakesley, D. & Hardwick, K. 2013. *Restoring tropical forests: a practical guide*. London. Royal Botanic Gardens, Kew.

Enters, T. & Durst, P.B. 2004. *What does it take? The role of incentives in forest plantation development in Asia and the Pacific*. Bangkok, FAO Regional Office for Asia and the Pacific.

FAO. 1995. *Forest Resources Assessment 1990: Global Synthesis*. FAO Forestry Paper 124. Rome.

FAO. 1999. *Code of Practice for Forest Harvesting in Asia-Pacific*. Bangkok, FAO Regional Office for Asia and the Pacific.

FAO. 2001. *Global forest resources assessment 2000*. FAO Forestry Paper 140. Rome.

FAO. 2008. *Contributions of the forestry sector to national economies, 1990–2006*. Forest Finance Working Paper FSFM/ACC/08. Rome.

FAO. 2008. *Re-inventing forestry agencies: Experiences of institutional restructuring in Asia and the Pacific*. Bangkok, FAO Regional Office for Asia and the Pacific.

FAO. 2009. *State of the World's Forests 2009*. Rome.

FAO. 2010. *Global forest resources assessment 2010*. Rome.

FAO. 2011a. *Forests beneath the grass*. Bangkok, FAO Regional Office for Asia and the Pacific.

FAO. 2011b. *Reforming forest tenure: Issues, principles and process*. Rome.

FAO. 2012. *Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security*. Rome.

FAO. 2014. *State of the World's Forests 2014*. Rome.

FAO. 2015. *Global Forest Resources Assessment 2015. Desk reference*. Rome.

FORRU (Forest Restoration Research Unit). 2005. *How to plant a forest: the principles and practice of restoring tropical forests*. Chiang Mai, Thailand, Biology Department, Science Faculty, Chiang Mai University.

Geist, H.J. & Lambin, E.F. 2002. Proximate causes and underlying driving forces of tropical deforestation. *Biotropica*, 52: 143–150.

Gilmour, D.A., San, N.V. & Xiong, T. 2000. *Rehabilitation of degraded forest ecosystems in Cambodia, Lao PDR, Thailand and Viet Nam: an overview*. Cambridge, UK, IUCN-Asia.

Goosem, S.P. & Tucker, N.I.J. 1995. *Repairing the rainforest – theory and practice of rainforest re-establishment in North Queensland's wet tropics*. Cairns, Wet Tropics Management Authority.

Hooijer, A., Page, S., Canadell, J.G., Salvins, M., Kwajdijk, J., Wosten, H. & Jauhiaren, J. 2010. Current and future carbon dioxide emissions from drained peatlands in Southeast Asia. *Biogeoscience*, 7: 1505–1514.

ITTO. 2002. ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests. ITTO Policy Development Series 13. Yokohama, Japan, ITTO.

Kanowski, J., Catterall, C.P., Procter, H., Reis, T., Tucker, N. & Wardell-Johnson, G. 2005. Biodiversity values of timber plantations and restoration plantings for rainforest fauna in tropical and subtropical Australia. *In* Erskine, P.D., Lamb, D. & Bristow, M., eds. *Reforestation in the tropics and subtropics of Australia using rainforest tree species*, pp. 183–205. Canberra, Rural Industries Research and Development Corporation.

Kaung, U.B. (in press). Forest restoration at the landscape level in Myanmar. *In* Appanah, S. & Leslie, R., eds. *Forest landscape restoration for Asia-Pacific forests*. Bangkok, FAO Regional Office for Asia and the Pacific and RECOFTC.

Lamb, D. 1998. Large-scale ecological restoration of degraded tropical forest lands: the potential role of timber plantations. *Restoration Ecology*, 6: 271–279.

Lamb, D. 2011. *Regreening the bare hills: Forest restoration in the Asia-Pacific region*. Dordrecht, Heidelberg, Springer.

Lamb, D., Erskine, P.D., and Parrotta, J.A. 2005. Restoration of degraded tropical forest landscapes. *Science*, 310: 1628–1632.

MacKinnon, K., Hatta, G., Halim, H. & Mangalik, A. 1996. *The ecology of Kalimantan: Indonesian Borneo*. Singapore, Periplus Editions (HK) Ltd.

Mansourian, S., Vallauri, D. & Dudley, N. eds (in cooperation with WWF International). 2005. *Forest restoration in landscapes: beyond planting trees*. New York, Springer.

McGuire, D. 2014. FAO's Forest and Landscape Restoration Mechanism. *ETFRN News*, 56: 58–65.

Mertz, O., Leisz, S., Heinimann, A., Rerkasem, K., Thiha, Dressler, W., Cu, P.V., Vu, K.C., Schmidt-Vogt, D., Colfer, C.J.P., Epprecht, M., Padoch, C. & Potter, L. 2009. Who counts? Demography of swidden cultivators in Southeast Asia. *Human Ecology* 37: 281–289.

Nawir, A.A., Gunarso, P., Santoso, H., Julmansyah & Hakim, M.R. (in press). Experiences, lessons and future directions for forest landscape restoration in Indonesia. *In* Appanah, S. & Leslie, R. (eds). *Forest landscape restoration for Asia-Pacific forests*. Bangkok, FAO Regional Office for Asia and the Pacific & RECOFTC.

Reynolds, G., Payne, J., Sinun, W., Mosigil, G. & Walsh, R.P.D. 2011. Changes in forest land use and management in Sabah, Malaysian Borneo, 1990–2010, with a focus on the Danum Valley region. *Philosophical Transactions of the Royal Society of London, series B, Biological sciences*, 366(1582): 3168–3176 (available at http://rstb.royalsocietypublishing.org/conent/).

RFRI. 2015. *Rain Forest Restoration Initiative* (available at http://www.rainforestation.ph/).

Russell, A.E., Cambardella, C.A., Ewell, J.J. & Parkin, T.B. 2004. Species, rotation, and life form diversity on soil carbon in experimental tropical ecosystems. *Ecological Applications*, 14: 47–60.

Shono, K., Davies, S.J. & Chua, Y.K. 2007. Performance of 45 native tree species on degraded lands in Singapore. *Journal of Tropical Forest Science*, 19: 25–34.

Toh, S.M. & Grace, K. 2005. *Case study: Sabah forest ownership*. Bangkok, FAO Regional Office for Asia and the Pacific.

Troup, R.S. 1921. *The silviculture of Indian trees*. Vol. II. Oxford, Clarendon Press.

Winterbottom, R. 2014. *Restoration: It's about more than just the trees*. World Resources Institute (available at http://www.wri.org/).

Wooster, M.J., Perry, G.L.W. & Zoumas, A. 2012. Fire, drought and El Niño relationships in Borneo (Southeast Asia) in the pre-MODIS era (1980–2000). *Biogeosciences*, 9: 317–340.

WRI (World Resources Institute). 2013. *An opportunity for Asia*. *World Resources Institute* (available at http://pdf.wri.org/forest_restoration_asia_brochure.pdf).

Wyatt-Smith, J. 1963. *Manual of Malayan Silviculture for Inland Forests*. Malayan Forest Record No. 23. Kepong, Malaysia, Forest Research Institute.

Zhou, Y.Y., Morris, J.D., Yan, J.H., Yu, Z.Y. & Peng, S.L. 2002. Hydrological impacts of reafforestation with eucalypts and indigenous species: a case study in southern China. *Forest Ecology and Management*, 167: 209–222. ◆

Restoration of the Baekdudaegan mountains in the Republic of Korea

W. Cho and B.K. Chun

© ROGER SHEPHERD

The Baekdudaegan protected area constitutes an interesting example of restoration that also has the potential to contribute to regional collaboration.

Woo Cho is Professor, working in the Division of Tourism, Sangji University, Republic of Korea.
Bom Kwon Chun is Senior Forestry Officer with FAO's Forestry Department, Rome, Italy.

In this article, we briefly introduce the ecological and sociocultural values of the Baekdudaegan area and ongoing efforts to protect it. The Baekdudaegan mountains constitute a mountain range of approximately 1 400 km in length that runs through the Korean peninsula, from Mt. Baekdu in the north to Mt. Jiri in the south. In keeping with the traditional principle that "Mountains divide water, but water does not cross mountains," the Baekdudaegan ridge is a watershed that delineates the Korean peninsula. Broadly speaking, the Baekdudaegan can be considered to include one major mountain range, known as the Jeonggan, and 13 secondary mountain ridges, known as the Jeongmaek, together demonstrating that mountains are not just points but lines and planes that are interconnected with other mountains and the people who live there (Figure 1). Although there has been deforestation in the part of the Baekdudaegan corresponding to the Democratic People's Republic of Korea (hereafter referred to as North Korea), this article focuses on the part corresponding to the Republic of Korea (hereafter referred to as South Korea), for which there is more information available.

Above: Hwangjang-san mountain in the Baekdudaegan

1
Ridge of the Baekdudaegan (thicker line) and those of the Jeongmaek and the Jeongmaek (thinner lines)

Source: KFS.

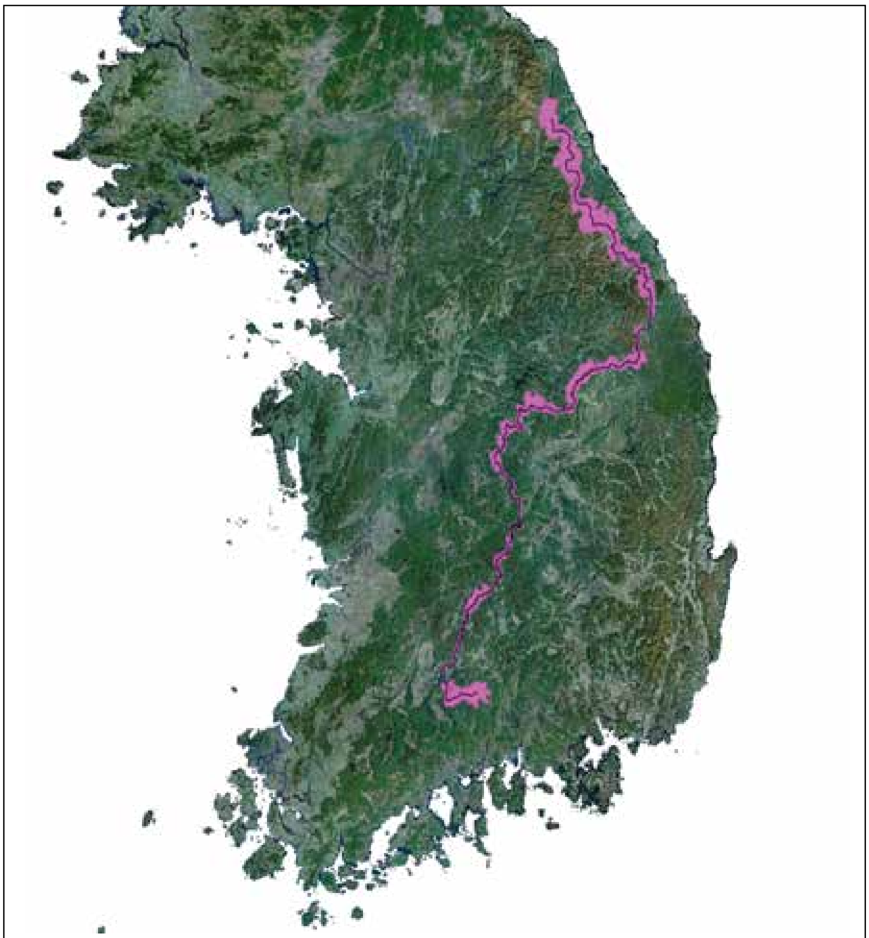
For the past 50 years, South Korea has witnessed rapid industrialization and urbanization, which has taken a heavy toll on the country's natural landscape. In order to mitigate this massive degradation, the country has adopted several systems for protecting its natural forests and landscapes. The Baekdudaegan, the ecological backbone of the country, had suffered considerably from limestone quarrying and road construction. Since 1990, thanks to heightened public awareness of the issues at stake, South Korea has engaged in protecting the Baekdudaegan, emphasizing the traditional Korean conception of geography. The Korea Forest Service (KFS) therefore started establishing the legal framework to pass the Baekdudaegan Protection Act in 2003 and designated the Baekdudaegan protected area (PA) in 2005. According to this legal framework, the South Korean part of the Baekdudaegan range measured 701 km in length in 2015, with an area of 2 750.77 km^2 (Figure 2).

Understanding mountains and mountain ranges is of particular importance to maintaining forested landscapes in these areas.[1] The Baekdudaegan is made up of more than 500 peaks and mountains, ranging in altitude from 200 m to 1 915 m above sea level. Its climate is considered to be temperate monsoon, with an average temperature of 6–12 °C and annual precipitation varying between 1 091 and 1 985 mm. According to research carried out in the area, 1 835 plant species, or 41.3 percent of all plant species in South Korea, can be found in the Baekdudaegan area (National Institute of Biological Resources, 2015).

STATUS OF DEGRADED LANDSCAPE IN THE BAEKDUDAEGAN PROTECTED AREA

There are many degraded sites in the Baekdudaegan protected area. KFS (2010) registered 302 sites in Baekdudaegan PA, categorizing forests and other land-use types related to the construction of roads, military bases, quarries, mines and dams (Table 1). Within the Baekdudaegan PA, most privately owned areas that had been used for agriculture, with a corresponding use of fertilizer and pesticide, were severely degraded (Figure 3). Limestone quarrying and mining have also been major drivers of degradation; from 1970 to 1980, the area was popular for such activities, but when they were wound down the affected parts were not properly managed or restored (Figure 3).

[1] The Baekdudaegan having been neglected for some 100 years, KFS published a book in March 1996 entitled *Baekdudaegan Literature Collection*, based on relevant historical documents, in order to reacquaint the public with the area and assess its ecological and sociocultural values.



Source: KFS.

2
Map of the South Korean Baekdudaegan protected area

TABLE 1. Degraded sites in the Baekdudaegan protected area

Land-use types	Number of sites
Farmland	162
Ranch	10
Road	63
Dam	4
Residential	4
Industrial	2
Military facilities	3
Telecommunication facilities	2
Public services	5
Other built-up	8
Quarry	11
Mine	10
Abandoned	11
Others	7
Total	**302**

Source: KFS, 2010.

3
Farmlands (left) and abandoned quarries (right) in the Baekdudaegan protected area

© W.CHO

© Y.H.CHOI

CONSERVATION EFFORTS IN THE BAEKDUDAEGAN PROTECTED AREA

KFS recognized the need for a better legal framework for protecting the Baekdudaegan. On the introduction of the Baekdudaegan PA, there were conflicts among central and local governments, local residents and many other stakeholders, but after numerous public hearings and discussions, a consensus was reached. In December 2003, the National Assembly, the legislative body of South Korea, enacted the Baekdudaegan Protection Act, which authorizes KFS to conserve the Baekdudaegan. In September 2005, KFS designated 2 634.27 km^2 (2.6 percent of the total area of South Korea) as the Baekdudaegan PA, based on a law that covers 6 provinces, 32 cities and counties, and 108 towns, townships and neighbourhoods, with a total population of 2.2 million (4.5 percent of the population of South Korea). In January 2015, the total protected area increased to 2 750.77 km^2, thanks to efforts by KFS to extend the Baekdudaegan PA by purchasing private properties located inside the area.

In cooperation with other government bodies and local communities, KFS has implemented various policies to manage natural resources in the Baekdudaegan PA and has a separate division exclusively for planning and managing the area and supporting long-term academic research. The first 10-year Basic Plan was developed to manage the Baekdudaegan from 2006 to 2015, and between 2006 and 2013, US$1.4 billion were invested to implement the plan. In order to protect the Baekdudaegan more comprehensively, academia and local communities joined forces to support programmes, demonstrate pilot restoration projects and educate citizens (Table 2).

KFS has also funded long-term monitoring and research into natural and sociocultural resources within the Baekdudaegan PA since 2006, with one activity focusing specifically on the Jeongmaek since 2009. In order to promote the Baekdudaegan PA internationally, an ecological network covering the Northeast Asian region and the Russian Federation has also been initiated by KFS. Within this network, several symposia and conferences have been held that have given better international visibility to the sustainable protection of the Baekdudaegan PA.

Educational activities for the general public have focused on strengthening national and international awareness of the Baekdudaegan. KFS has built several eco-education centres and managed educational programmes. In line with its educational activities, KFS produced a brochure, including a map, in order to raise awareness within the country and around the world (thanks to translations into multiple languages) about the Baekdudaegan's environmental characteristics, endangered species and national treasures.

Cooperation with stakeholders

Following the 2003 Baekdudaegan Protection Act, the designation of the protected area proved to be controversial and KFS had to amend its boundaries three times in one year to reflect stakeholders' opinions gathered via 242 public hearings, 520 press conferences, and promotional campaigns held during the first four months. Owing to these public participation processes, the final protected area was half of that initially

TABLE 2. Core projects of the Basic Plan for the Baekdudaegan

Goals	Tasks	Major projects
Ecological resources	• survey environmental and forest resources • restore degraded forested landscapes	• Baekdudaegan and Jeongmaek survey (2006–present) • Baekdudaegan ecosystem database (2006–present) • restore degraded ecosystems and develop ecosystem restoration model (2006–present) • manage forest resources (2006–present)
Sustainable use	• develop ecotourism programmes • restore cultural heritage • boost local economy	• establish natural recreational forest (2010–2015) • develop eco-education programmes (2007) • construct a Baekdudaegan arboretum (2010–present) • maintain trail facilities (2006–present) • assist local business (2006–present)
Building management capacity	• designate and manage protected areas • restrict activities in PA and ensure advance consultation • acquire private property in protected areas • establish a compensation system	• designate more protected areas for forest genetic resources (2006–2014) • acquire private properties (2006–2014) • expand protected areas (2013)
Public participation and education	• encourage public participation • promote public education	• clean up Baekdudaegan (2006–2014) • develop Baekdudaegan symbols and signposts (2006)

Source: KFS, 2014c.

TABLE 3. Opinions on government regulations and protection of the Baekdudaegan (%)

Category	General public (no. = 1,023)	Residents (no. = 130)	Experts (no. = 90)
Protection and regulation of the Baekdudaegan are **insufficient**	39.2	18.5	33.3
Protection and regulation of the Baekdudaegan are **appropriate**	35.6	46.2	52.2
Protection and regulation of the Baekdudaegan are **too strict**	4.2	26.9	8.9
Don't know/no answer	21.0	8.5	5.6

Source: KFS, 2013b.

4
*A Buddhist temple (*jikjisa*) in the Baekdudaegan*


© Y.H. CHOI

proposed (a decrease from 5 400 km^2 to 2 634.27 km^2) (KFS, 2006).

Another survey asked the general public and residents for their opinion on whether or not the protection and regulation of the Baekdudaegan PA were at an appropriate level. Of the general public, 39.2 percent of respondents answered that protection and regulation of the Baekdudaegan were "insufficient", whereas 35.6 percent felt that they were "appropriate" (Table 3). A consensus on the protection of the Baekdudaegan was also reached among local residents. Of them, 46.2 percent responded that protection and regulation of the Baekdudaegan were "appropriate". However, 26.9 percent answered that regulation was "too strict," suggesting that many local residents are still dissatisfied with the conservation of the Baekdudaegan PA by KFS (KFS, 2013b).

Long-term monitoring of the Baekdudaegan

In accordance with Article 12 of the Baekdudaegan Protection Act, KFS and local governments have provided financial support to academic research for the monitoring of natural and sociocultural resources and the development of associated technology needed to protect the Baekdudaegan. Accordingly, KFS has been monitoring natural resources in the whole area since 2006, including a survey of the Jeongmaek. Long-term monitoring and research for the whole Baekdudaegan PA has been divided into five sections and one section is surveyed per year, i.e. five years for one round. The first round of monitoring was conducted in the period 2006–2010; the second round began in 2011 and is expected to finish in 2015. The research monitors not only natural resources, including geology, flora and fauna (mammals, birds, reptiles and amphibians), and forest landscape, but also sociocultural resources and the level of satisfaction of local community support programmes.

The Baekdudaegan PA can be described as a 701-km-long ecological corridor. Results of the long-term monitoring also show that it is a biodiversity hotspot, with more than one-third of the plant species of South Korea (1 326 out of 4 701) found in the PA. Of the 1 326 plant species, 108 are listed as endemic and 56 as rare species. There are also 30 animal species that are endangered (according to the Convention on International Trade in Endangered Species of Wild Fauna and Flora definition). For these reasons, the Baekdudaegan PA includes 7 national parks, 44 protected areas for forest genetic resource conservation and 66 wild animal sanctuaries. The area also plays a critical role for water resources, since major rivers, such as the Han and the Nakdong, have their source in the Baekdudaegan PA (KFS, 2011; KFS, 2012; KFS, 2013a; KFS, 2014a; KFS, 2014b; KFS, 2014c).

The Baekdudaegan PA has a rich cultural heritage, with 21 heritage sites. Buddhism in particular has left an important mark. Of 935 traditional Buddhist temples in South Korea, 173 are located in the Baekdudaegan PA or neighbouring areas (Figure 4). There are also numerous old villages, distilleries and traditional markets; as well as a total of 2 008 registered cultural assets, including 32 national treasures and 304 treasures (Seo, 2013).

© KFS © Y.H. CHOI

5
An ecological bridge constructed over the road crossing the Baekdudaegan ridge, Ihwaryeong (left: before construction; right: after construction)

The results of the monitoring and research have been used to develop and implement management policies for the Baekdudaegan PA, and have been shared with other government organizations, such as the Korea National Arboretum, the Korea Forest Research Institute, the Ministry of Environment and the Korea National Park Service. KFS is currently preparing the third round and is collecting experts' and local residents' opinions. The monitoring and research results have also been used to register the Baekdudaegan in international databases covering protected areas. Since 2012, KFS has been investigating the possibility of the Baekdudaegan's listing as a UNESCO World Heritage site.

Restoration of forested landscape in the Baekdudaegan

Like most mountain areas in South Korea, the Baekdudaegan has been heavily exploited for fuelwood and other natural resources. Many military bases that were constructed on top of the mountains have also degraded its forested landscapes. Restoration in the Baekdudaegan focuses on three major tasks: restoration of degraded landscapes and landslide protection, reforestation and revegetation, and protection of wildlife and their habitats. Since the enactment of the Baekdudaegan Protection Act, several ecosystem restoration projects have been carried out. As of 2005, KFS has built several eco-bridges to reconnect the fragmented Baekdudaegan ecological corridor, restored abandoned military bases, quarries and mines, protected endangered species, and maintained trail facilities with a budget of US$59 million (KFS, 2014c).

Since 2012 in particular, ecological corridors have been established following the major ridges of Ihwaryeong, Yuksipryeong and Beoligae in order to reconnect fragmented areas and help wild animals to move (Figure 5). KFS has also purchased abandoned schools and resting areas for use as ecological education centres.

An example of restoration by KFS: an abandoned military base in Baramjae

In Baramjae, one of the Baekdudaegan's major ridges, military facilities such as bunkers, water tanks, and access roads were constructed in the 1970s but are no longer used (Figure 6). A restoration project began there in 2007 with a preliminary site survey and expert meetings. In 2008, a detailed ecological survey was carried out and a restoration plan was established during the course of 2009 and 2010. Actual restoration was carried out in 2010 and 2011, with the aim of restoring the original forested landscape. Saplings of *Quercus mongolica*, a dominant tree species in this region, were transplanted, and other herbaceous plants and shrubs whose seeds were collected in the region were seeded to facilitate the establishment of the vegetation community.

An example of restoration by a private party: limestone mine in Mt. Jabyeong

Located in the centre of the Baekdudaegan, Mt. Jabyeong is one of the largest limestone regions in the Korean peninsula. The limestone quarry opened in 1978, and since 2000 Lafarge Halla Cement Co. has continued mining.

As public awareness of the value of the Baekdudaegan increases, a conflict of interest between environmental protection and economic interests has emerged. This has been dealt with through continuous negotiations between Lafarge Halla Cement Co. and local environmental groups who agreed that the company would not extend its mining site further into the main ridge of the Baekdudaegan and would cooperate on initiating the Eco-Baekdudaegan 2+ Movement environmental fund together with local environmental groups.

Thanks to this fund, the environmental groups are conducting various community

© KFS

6
Restoration of abandoned military base and access roads in Baramjae (left: before restoration; right: after restoration)

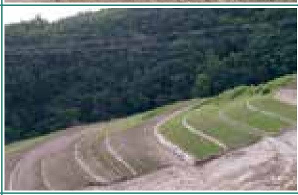
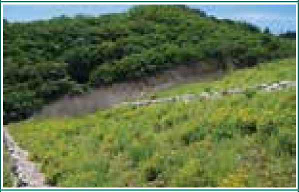
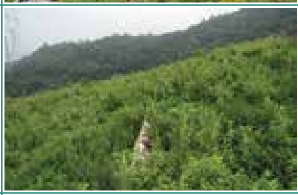
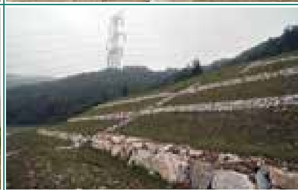
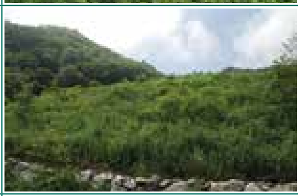
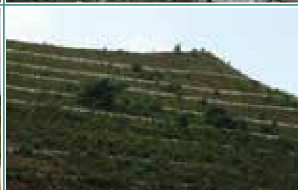
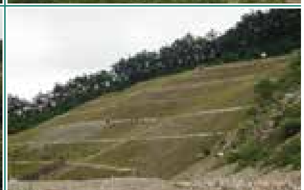
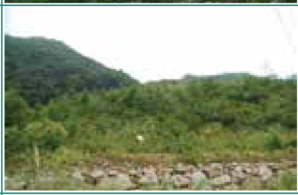
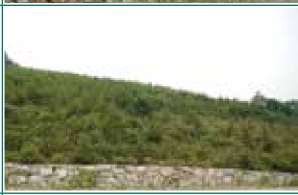
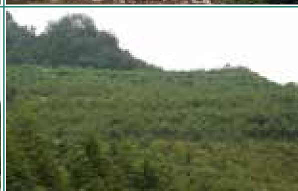
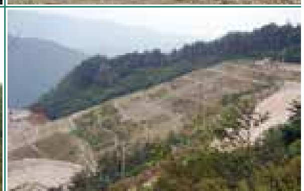
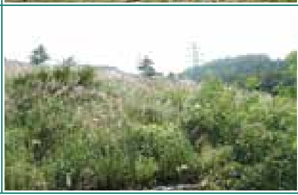
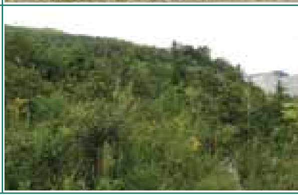
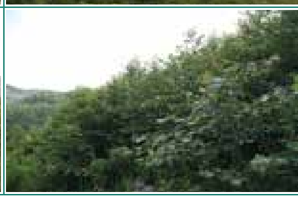
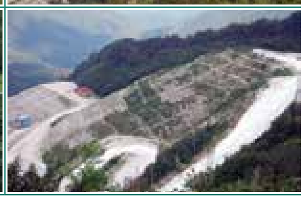
activities, including environmental education. Moreover, restoration of the closed quarry site was conducted by an independent third party. A quarry restoration monitoring committee, consisting of the government, experts, non-governmental organizations and residents, was established and continuously monitors and advises on the quarry site restoration. A Forest Restoration Conference has been held annually since 2014, with the assistance of KFS's Central Mountain Management Commission.

© W. CHO

7
Limestone quarry in Mt. Jabyeong

8

Annual changes in vegetation community in the pilot site for restoration in Okgye quarry, Mt. Jabyeong

Year	Restored in 2007	Restored in 2008	Restored in 2009	Restored in 2010
2007				
2008				
2009				
2010				
2011				
2012				
2013				
2014				

Source: Lafarge Halla Cement Co., 2014.

The restoration of the quarry is a complex long-term project. A pre-site inspection and pilot project were carried out between 2007 and 2010. An intermediate restoration of areas where mining was completed has been carried out and is continuously monitored (Table 4). Figure 8 illustrates how vegetation has been slowly established in the restored quarry area.

TABLE 4. Areas of restored quarry sites by the Lafarge Halla Cement Co. in 2007–2010 (ha)

Restoration	2007	2008	2009	2010	Total
Pilot restoration	1.5	5.5	5.0	5.0	17.0
Intermediate restoration	2.7	4.3	7.5	3.0	17.5
Total	**4.2**	**9.8**	**12.5**	**8.0**	**34.5**

Source: Lafarge Halla Cement Co., 2012.

SUCCESSES AND CHALLENGES OF THE BAEKDUDAEGAN PROTECTED AREA

Long-term monitoring shows that the Baekdudaegan PA has many natural and sociocultural resources. Based on this, we proposed a peninsula-scale ecological network connecting the Baekdudaegan to the Jeongmaek and even smaller forests and green spaces in urban areas. We described this idea as a "nationwide forest eco-network with the Baekdudaegan as a backbone", which would play a core role in the conservation of regional forest landscape and biodiversity in both South and North Korea (Figure 9). We believe that the experience in forest restoration in mountainous areas gained during the restoration projects will be useful for future ecosystem restoration throughout the nationwide forest eco-network.

Collaboration with local communities is essential for effectively managing the Baekdudaegan PA. According to KFS (2011, 2012, 2013a, 2014b, 2014c), 60 percent of local residents were satisfied with the community support programmes, which spent a total of US$9.1 billion, supported by KFS. The programmes aim to build communities' capacity, enhance manufacturing and storage facilities, assist in marketing forest products, and construct industrial complexes for forest products (Table 2). It was estimated that the programmes increased production of non-timber forest products by 20–30 percent. Although there is no accurate estimate of the increase in the local community's income, there is indirect evidence that the support programme has been effective in boosting this income. For instance, local residents had a higher level of participation in community programmes and received greater economic support from KFS in relation to the protection of the Baekdudaegan (KFS, 2011; KFS, 2012; KFS, 2013a; KFS, 2014b). Also, local residents showed greater willingness to cooperate in preparing for the area's listing as a UNESCO biosphere reserve, all of which suggests that KFS's community support programme can be a model for other protected areas.

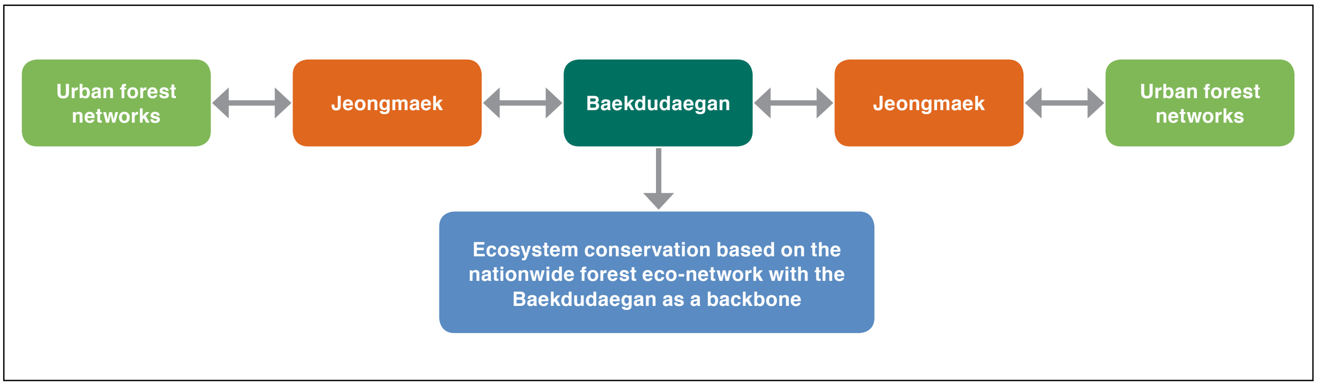
Despite these many indications of success, there are still a number of practical difficulties to overcome.

Firstly, a large proportion of the Baekdudaegan PA overlaps with other types of protected areas. Because different protected areas are managed by other government organizations with different managerial goals, there have been conflicts between organizations.

Secondly, although KFS spends considerable amounts on administrative and technical support for managing the Baekdudaegan PA, it is still short of funds and has difficulty controlling visitors to the area. As the Baekdudaegan becomes more popular, it is also becoming crowded by visitors. Today, disturbances caused by visitors, such as direct physical destruction of vegetation and soil erosion along trails, are one of the most serious problems in conserving the Baekdudaegan PA. Funds are needed to hire and operate field rangers, as well as to monitor and research the impacts of tourism on the ecosystem.

Thirdly, the Baekdudaegan PA has only been designated on the South Korean side. This means that the current Baekdudaegan PA represents only half of the ecological and sociocultural value of the total Baekdudaegan area. We believe that the Baekdudaegan can help enhance peace in

9
Nationwide forest eco-network with the Baekdudaegan as a backbone



this region if the two Koreas collaborate to conserve it. The area also has the potential to be a Northeast Asian ecological axis by connecting other protected areas in China and the Russian Federation (Cho, 2014). There may be numerous obstacles to overcome, but fortunately neighbouring countries are in agreement about conserving natural forested landscape in this region. It may take a long time, but we trust that we will achieve this goal and contribute to peace in the region. ◆

References

Cho, W. 2014. *Challenges for conserving and exploring other values of Baekdudaegan Regions*. Paper presented at the Symposium for Ecological Axis of Northeast Asia, Seoul, Republic of Korea, 4 October.

KFS. 2006. *Baekdudaegan Mt. white paper.* KFS, Daejeon, Republic of Korea.

KFS. 2010. Database of degradation in the Baekdudaegan protected area. KFS, Daejeon, Republic of Korea.

KFS. 2011. *Natural resources change survey and management practice study of the Baekdudaegan mountains*. KFS, Daejeon, Republic of Korea.

KFS. 2012. *Natural resources change survey and management practice study of the Baekdudaegan mountains*. KFS, Daejeon, Republic of Korea.

KFS. 2013a. *Natural resources change survey and management practice study of the Baekdudaegan mountains*. KFS, Daejeon, Republic of Korea.

KFS. 2013b. *Survey on the awareness of the Baekdudaegan*. KFS, Daejeon, Republic of Korea.

KFS. 2014a. *Natural resources change survey and management practice study of the Baekdudaegan mountains*. KFS, Daejeon, Republic of Korea.

KFS. 2014b. *Baekdudaegan*. KFS, Daejeon, Republic of Korea.

KFS. 2014c. *Assessment of the Basic Plan for the Baekdudaegan Protection and a study of the direction of the Second Basic Plan.* KFS, Daejeon, Republic of Korea.

Lafarge Halla Cement Co. 2012. *Annual report on vegetation restoration for the Okgye quarry in Mt. Jabyeong.*

National Institute of Biological Resources. 2015. Website (available at www.nibr.go.kr/species) [in Korean].

Seo, J.C. 2013. *Mountains and Buddhism culture of the Baekdudaegan mountains, Korea*. Symposium for Cooperating Protected Areas Management of Northeast Asia, pp.31–50. ◆

Transforming China's forests

C. Daoxiong, G. Wenfu, L. Zhilong and S. Dongjing

Experimental management approaches could transform China's vast plantation forests and degraded lands into close-to-nature forests.

Professor Cai Daoxiong is Director, Experimental Center of Tropical Forestry, Piangxiang, China.
Professor Guo Wenfu, **Dr Liu Zhilong** and **Ms Sun Dongjing** are scientists, also at the Experimental Center of Tropical Forestry.

China is engaged in a massive reforestation programme with the aim of redressing the environmental problems caused by previous deforestation. But some of the new forests are experiencing difficulties. In southern China, monocultures of eucalypts and conifers are at high risk of attack by forest pests and are suffering declines in soil fertility. Their sustainability is in jeopardy.

More than a decade ago, scientists at the Experimental Center of Tropical Forestry (ECTF) perceived a need to move Chinese forestry towards "close-to-nature" approaches that would make greater use of native species and create resilient, species-diverse forests. In 2004, the ECTF began cooperating with scientists at the University of Freiburg in Germany, and in 2008 it embarked on an experimental programme to test a range of approaches to close-to-nature forestry. The results are now starting to materialize.

This article describes China's massive reforestation programme, the increasing need to diversify the plantations, the philosophy behind the ECTF's close-to-nature approach, and two of the eight experimental close-to-nature designs that are being tested in subtropical China.

***Above:** Professor Cai (right) presents the close-to-nature approach to Dr Li Chao (middle) from the Northern Forestry Centre, Natural Resources Canada, in a rehabilitation site consisting of patches of 30 native broadleaved species in the Experimental Center of Tropical Forestry*

CHINA'S REFORESTATION PROGRAMME

Two major reforestation initiatives were launched in China in 1999: the Natural Forest Protection Programme, and the Conversion of Cropland to Forest Programme, also known as "Grain-for-Green" and "Sloping Land Conversion", respectively. These and other major ecological programmes (such as the Three-North Shelterbelt Programme) have several purposes, including addressing severe environmental problems, such as flooding, soil erosion and desertification, and helping to meet China's escalating demand for wood.

China's reforestation programme has made significant progress, with the forest area increasing by an average of 3.0 million ha per year between 2000 and 2010 (FAO, 2010). At the United Nations Summit on Climate Change in December 2009, President Hu Jintao committed China to increasing its forest area by 40 million ha by 2020 compared with 2005 and its timber stock to 14 billion m^3.

By 2013, China had an estimated 69 million ha of planted forests, including 13 million ha planted since 2008 (State Forestry Administration, 2014). The total forest area, including natural forests, is about 207 million ha (FAO, 2010), and this is likely to expand further in coming decades. A large proportion of the new forests will help make up the "Great Green Wall" stretching from Xinjiang Province in China's northwest to Heilongjiang Province in the northeast, but large new areas of planted forests have also been established in southern areas, including Guangxi Autonomous Region, Yunnan Province, Guangdong Province and Hainan Province, all of which are either tropical or subtropical.

THE NEED TO DIVERSIFY

Most of China's new forests are monocultures of fast-growing species thought to have high economic potential, such as *Eucalyptus*, poplars (*Populus* spp.), larch (*Larix* spp.), *Cunninghamia lanceolata* and *Pinus massoniana*. For example, the main planted species in Guangxi are *Pinus massoniana*, *Cunninghamia lanceolata* and a Eucalyptus hybrid (*Eucalyptus grandis* x *E. urophylla*). Not all the new forests have established themselves successfully, however, especially in marginal areas. Moreover, many plantations have begun to exhibit low productivity, poor soil stability and a high vulnerability to pest and diseases, and their biodiversity is low. For example, even with the addition of fertilizers, the productivity of the second, third and fourth generations of *Eucalyptus* plantations in the ECTF has been shown to decrease by 20 percent, 28 percent and 46 percent, respectively, compared with the first generation (Yu, Bai and Xu, 1999).

The Experimental Center of Tropical Forestry

The ECTF, which is part of the Chinese Academy of Forestry, is located near Pingxiang in Guangxi Autonomous Region, southern China. Guangxi's naturally occurring monsoon evergreen broadleaved forests and tropical monsoon forests have largely been lost due to long-term intensive activities such as timber harvesting, woodfuel collection and conversion to agriculture. Monocultural tree plantations, natural secondary forests and shrub–grass formations are now common.

Guangxi Autonomous Region is part of the hilly forest region – which also includes parts of the provinces of Anhui, Fujian, Guangdong, Hubei, Hunan, Jiangxi and Zhejiang – in southeastern China that grow most of the country's timber and industrial fibre. Monocultural forest plantations have been a major land use in Guangxi for nearly 90 years, including at the ECTF.

The Guangxi Longzhou Forest Farm in Guangxi was established for wood production in 1927 and planted mainly with *Pinus massoniana* (Masson's pine) and *Cunninghamia lanceolata* (Chinese fir). This state-owned estate became the Guangxi Daqingshan Experimental Bureau in 1979. In 1991 it was renamed the ECTF and designated as one of 21 subordinate bodies of the Chinese Academy of Forestry, thus becoming a national base for forest-related scientific experimentation and demonstration.

© A. SARRE

The headquarters of the Experimental Center of Tropical Forestry nestles among limestone peaks and rice paddies near Pingxiang, Guangxi Autonomous Region

TABLE 1. Changes in micro-organisms and nutrition in the surface soil of first- and second-generation *Pinus massoniana* plantations

		First generation	Second generation	Percentage decrease in second generation
Quantity of micro-organisms ('000 colony-forming units per gram of soil)	Bacteria	146.0	101.0	30.7
	Actinomycetes	24.6	24.0	2.52
	Fungi	22.7	11.3	50.3
	Nitrogen-fixing bacteria	9.58	3.29	65.7
Enzyme activity (milligrams per gram of soil per hour)	Polyphenol oxidase activity	0.14	0.04	71.4
	Urease activity	0.04	0.03	25.0
	Protein enzyme activity	0.26	0.06	76.9
Nutrition (milligrams per kilogram of soil)	Available nitrogen	89.4	78.7	11.9
	Available phosphorus	1.12	0.97	13.4
	Calcium	9.07	4.57	49.6

Source: ECTF field data.

Declines in soil quality and fertility are also measurable. For example, second-generation *Pinus massoniana* plantations in the ECTF have lower densities of soil micro-organisms and lower nutrition than first-generation plantations (Table 1). Moreover, the pine caterpillar (*Dendrolimus punctatus*) has defoliated significant areas of *Pinus massoniana* plantations.

CLOSE-TO-NATURE FORESTRY

Close-to-nature forestry is a potential way of controlling and gradually diminishing the risks to monocultural forests posed by storm damage, pest outbreaks and other threats through the use of simple management interventions. Rather than mimicking nature, close-to-nature forestry uses it to best advantage: the aim is to achieve a healthy, functioning, productive forest that is resilient to change and economically profitable, using as few human interventions as possible. Genetic and structural diversity help confer resilience, which is a precondition for species in adapting to changing climatic conditions. The large number of trees that are established through natural regeneration in close-to-nature forests means that genetic recombination is an ongoing process, helping to maintain genetic diversity (Küchli, 2013). The ECTF applies four basic operating principles:

© EXPERIMENTAL CENTER OF TROPICAL FORESTRY

Defoliation in a plantation of* Pinus massoniana *caused by pine caterpillar, Guangxi Autonomous Region

1. Native species should be used wherever possible, but introduced species may also be used if they are adapted to local conditions and will not be invasive.
2. The structure of stands should be stable, with the capacity for ongoing natural succession.
3. Notwithstanding commercial objectives, close-to-nature forestry should make use of natural processes to the greatest extent possible.
4. Management should be adaptive, requiring that forest health and the effects of interventions are monitored closely over time.

The ECTF's multifunctional, close-to-nature forest research has six main components:

1. Improving the quality of seedlings by using high-quality seeds, applying containerized seedling systems, and cultivating large, robust seedlings for planting.
2. Using the most suitable tree species for each site.
3. Adjusting stand density in line with the quality of seedlings, site conditions and management objectives.
4. Shifting from monocultures to mixed-species plantations in line with close-to-nature principles.
5. Exploring effective arrangements of tree species in mixed forests to achieve optimal growth rates and tree form and ensure efficient planting, tending and harvesting practice.
6. Developing species mixes in *Eucalyptus* plantations involving high-value native broadleaved species to attenuate the soil degradation associated with large-scale *Eucalyptus* plantations.

The long-term aim of the ECTF's research is to develop multifunctional, close-to-nature forestry that ensures ecosystem sustainability, achieves high tree growth rates, generates income in the short term and over the longer term, and produces large-diameter trees of broadleaved species suitable for high-value end uses such as the manufacture of furniture.

Two of the ECTF's experimental designs are presented below. The design in case study 1 aims to move existing monocultural conifer plantations towards close-to-nature forests. The design in case study 2 aims to restore degraded forest land.

CASE STUDY 1: SHIFTING EXISTING MONOCULTURAL CONIFER PLANTATIONS TOWARDS CLOSE-TO-NATURE FORESTS

In China, monocultural plantations of *Pinus massoniana* and *Cunninghamia lanceolata* have traditionally been managed according to a standard thinning regime. With an initial planted density of 3 000 stems per ha, weeding and tending practices are carried out six times in the first three years to reduce competition on planted seedlings. A release thinning is carried out at year 7 to remove suppressed and poorly formed trees, reducing stand density to 1 650 stems per ha. A second thinning is conducted at year 11, reducing stand density to 1 050 stems per ha.

The management model

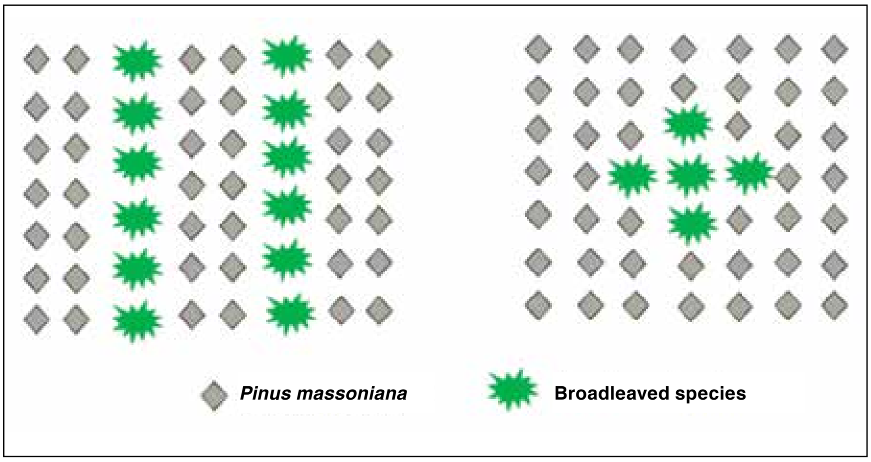
With a view to moving these monocultural conifer plantations towards close-to-nature forests, an experiment was conducted in plantations of *Pinus massoniana* and *Cunninghamia lanceolata* established in 1993. The second thinning was carried out at year 15 (2007, instead of year 11, which is the standard practice), in which high-quality stems were retained at varying densities. The best-formed dominant individuals were marked as "potential crop trees", the aim being to provide these trees with optimal canopy space by removing individuals that interfere with their growth, allowing them to grow at the fastest possible rate while maintaining the best-possible form.

In 2008 (year 16 of the plantations), two-year-old containerized seedlings of high-value local broadleaved species were planted (in holes 50 cm × 50 cm wide and 30 cm deep) in the stand openings created by the thinning event in the previous year. Two configurations were used (Figure 1):

1. seedlings distributed evenly throughout the stand at a spacing of 5.4 m; and
2. clusters of five seedlings planted with a spacing between clusters of 10 m.

The species used for interplanting were *Castanopsis fissa*, *Castanopsis hystrix*, *Erythrophleum fordii*, *Mglietia glauce*, *Mesua ferrea* and *Michelia hedyosperma*. Each of these broadleaved species is native to the region and suitable for growing at the experimental site; *Erythrophleum fordii* is also a nitrogen-fixing species.

The plantings of high-value species were tended 2–3 times per year for the first three years. In year 4 or 5, the high-value trees



1
Two approaches to intercropping high-value broadleaved species in openings in a* Pinus massoniana *stand: in-line planting (left) and cluster planting (right)

This **Pinus massoniana** *plantation is in the process of converting to a close-to-nature broadleaved forest in the Experimental Center of Tropical Forestry*

© EXPERIMENTAL CENTER OF TROPICAL FORESTRY

were pruned to remove lower lateral and dead branches and poorly formed higher branches to ensure that the young trees develop symmetrical canopies.

As the plantation continues to grow, stand density is being adjusted to provide an optimal growth environment for the broadleaved trees as well as for the conifer crop trees. *Pinus massoniana* and *Cunninghamia lanceolata* trees will be harvested selectively as they reach an appropriate size (diameter at breast height [dbh] = 40 cm), and these species will not be replanted. The high-value species will be encouraged to regenerate naturally so that, over time, the original conifer plantations will shift towards close-to-nature broadleaved forests.

Results

Potential crop trees achieved a higher mean annual diameter increment at lower stand densities for both *Cunninghamia lanceolata* and *Pinus massoniana* (although the total stock volume of these species was reduced because of the higher rate of thinning). This finding is in accordance with standard forestry practice, but it is stressed here because of its importance to the overall silvicultural strategy.

Table 2 shows that of the six native, high-value broadleaved species planted, *Castanopsis fissa* achieved the best growth rates five years after planting, followed by *Manglietia glauce*, *Castanopsis hystrix*, *Erythrophleum fordii*, *Michelia hedyosperma* and *Mesua ferrea*. *Castanopsis fissa*, *Manglietia glauce*, *Castanopsis hystrix* and *Erythrophleum fordii* are particularly well suited to planting under *Pinus massoniana* and *Cunninghamia lanceolata*. For all species, the best height and diameter growth was achieved in stands thinned at the highest intensity.

TABLE 2. Growth of broadleaved species planted in 15-year-old plantation forests with differing thinning intensities (and therefore upper-storey densities), five years after planting

Species in upper storey	Broadleaved species	Thinning intensity					
		High*	Medium	Low	High	Medium	Low
		Average height (m), 2012			Average diameter (cm), 2012		
Pinus massoniana	*Castanopsis hystrix*	5.1	4.4	4.2	3.5	2.9	2.8
	Michelia hedyosperma	3.8	3.3	3.0	4.0	3.4	3.2
	Castanopsis fissa	9.1	8.8	8.1	8.5	8.1	7.6
	Erythrophleum fordii	3.5	3.3	3.0	2.7	2.4	2.2
	Manglietia glauce	7.4	7.0	6.8	7.1	6.9	6.5
	Mesua ferrea	1.3	1.0	0.8	1.5	1.3	1.1
Cunninghamia lanceolata	*Castanopsis hystrix*	5.6	5.0	4.5	4.1	3.6	3.0
	Michelia hedyosperma	4.1	3.5	3.1	4.3	3.8	3.3
	Castanopsis fissa	9.4	8.9	8.3	8.8	8.5	8.0
	Erythrophleum fordii	4.8	4.6	4.5	4.3	4.0	3.8
	Manglietia glauce	8.1	7.5	7.0	7.7	7.2	6.3
	Mesua ferrea	1.4	1.2	1.0	1.8	1.5	1.1

* *Note:* "high" = high thinning intensity (225–300 residual stems per ha); medium = medium thinning intensity (375–450 residual stems per ha); and "low" = low thinning intensity (600–750 residual stems per ha).

TABLE 3. Changes in biodiversity, close-to-nature stands versus no treatment

Upper-canopy species	Treatment	Canopy density*		Class of community	Biodiversity indicator					
					Number of species		Shannon-Wiener index**		Pielou's evenness index***	
		2007	2012		2007	2012	2007	2012	2007	2012
Pinus massoniana	Replacement planting	0.40	0.59	Trees	1.0	9.0	0	1.14	-	0.82
				Shrubs	34.0	47.0	1.31	2.78	0.81	0.89
				Herbaceous	11.0	15.0	0.86	1.46	0.78	0.70
	Control (i.e. no treatment)	0.81	0.86	Trees	1.0	1.0	0	0	-	-
				Shrubs	31.0	33.0	1.42	1.93	0.79	0.75
				Herbaceous	12.0	10.0	0.91	1.29	0.66	0.72
Cunninghamia lanceolata	Replacement planting	0.35	0.56	Trees	1.0	13.0	0	1.37	-	0.76
				Shrubs	35.0	45.0	1.44	2.58	0.69	0.80
				Herbaceous	15.0	18.0	1.12	1.82	0.81	0.79
	Control (i.e. no treatment)	0.80	0.86	Trees	1.0	1.0	0	0	-	-
				Shrubs	34.0	33.0	1.53	2.01	0.74	0.74
				Herbaceous	12.0	12.0	1.07	1.51	0.66	0.73

* Canopy density is the percentage of forest floor covered by the tree canopy, viewed from above.

** The Shannon-Wiener index increases as the richness and evenness of an ecological community increase, where evenness is a measure of the relative abundance of species.

*** Pielou's evenness index is another indicator of species' evenness. The closer this index is to 1, the more even the number of individuals of the different species.

Benefits

The amended thinning regimes help ensure that the planted *Pinus massoniana* and *Cunninghamia lanceolata* trees remain healthy and grow at an optimal rate. A focus on potential crop trees means that those trees will achieve a harvestable size earlier than under the traditional thinning regime, bringing the economic benefits forward. In the longer term, the high-value broadleaved species are expected to increase the value of the forest and yield high-value timbers, whose processing into furniture and other high-value products is likely to generate significant employment.

Table 3 shows that, by a range of measures, replacement planting increased floral biodiversity substantially in both *Cunninghamia lanceolata* and *Pinus massoniana* plantations between 2007 and 2012.

CASE STUDY 2: RESTORING DEGRADED FOREST LAND

Much of the land in southern China was once dense primary forest with rich biodiversity, large mature trees and little human interference. As China's population increased and human activity expanded, however, most of this primary forest was encroached upon and became degraded. Seriously degraded forests typically lack climax and subclimax tree species. Therefore there are no natural seed sources for these species and little prospect of developing climax and subclimax communities through natural regeneration or recreating primary forests through natural succession.

The ECTF has been investigating the restoration and rehabilitation of seriously degraded subtropical forest ecosystems since 1979. This research has been carried out at a 173-ha demonstration site in two phases:

1. Establish forest plant communities (1979–1986). The main activity in this phase was to introduce more than 30 indigenous pioneer species to the demonstration site; they were then out-planted in various arrangements according to their physiology and microsite conditions. By 1986, a mixed forest community comprising small monocultural blocks ("patches") had been established at the demonstration site.
2. Promote close-to-nature restoration (since 2002). The pioneer tree species used in the first phase were mostly incapable of forming subtropical climax forest. In addition, the single-species patches had low biodiversity and were unable to provide high-quality environmental services. Therefore, a close-to-nature restoration method was applied to prune trees and thin the single-species patches created in the first phase. In the spaces under the canopies created by these measures, climax and subclimax, long-lived, shade-tolerant tree species – such as *Aquilaria sinensis*, *Castanopsis hystrix*, *Parashorea chinensis*, *Phoebe bournei* and *Pterocarpus indicus* – were planted. In this way, single-stratum forests were transformed into mixed-species, uneven-aged forests, with a development trajectory towards climax forest.

The basis for the restoration approach is set out below:[1]

- *Dominant abiotic factors*. The ecological environment in China's subtropics is complex and composed of heterogenic microsites with many varying abiotic factors, such as those related to climate, aspect, slope, soils and site history. The adaptive capacity of tree species also differs, requiring that tree species are selected carefully in light of the abiotic factors that will apply during the restoration process (i.e. site-specific reforestation).
- *Ecological succession*. Ecological succession may be defined as the progressive change in species composition and forest structure caused by natural processes over time (ITTO, 2002). Ecological degradation, on the other hand, is the retrogressive succession of an ecosystem that has been disrupted and damaged, leading to changes in ecosystem structure, the loss of ecological functions, and disruptive interspecific relations. Restoration aims to ensure that the ecosystem has sufficient resilience to self-repair in the face of disturbances. Therefore, the ECTF restoration approach aims to use ecological succession to recreate the original ecosystem structure.
- *Niche-based theory of community assemblages*. A species occupies a certain multidimensional space in an ecosystem; the sum of the various environmental conditions and resources required by a species is called its niche, with the size of the niche reflecting the genetic, biological and ecological attributes of the population. In forest restoration, it is preferable to use tree species with differing niches to avoid direct competition and to create plant communities that occupy different strata, both temporally and spatially. A diversity of niches can facilitate increases in biodiversity over time and increase the productivity and functionality of the ecosystem.
- *Restoration ecology*. Restoration ecology supports the adoption of techniques and methods to initiate or accelerate the recovery of an ecosystem with respect to its health, integrity and sustainability.

Restoration practice

The restoration technique now employed at the experimental site – having been revised over time in the light of experience – is described in general terms below:

Planting. The initial planting density is 2 m × 2 m using 1-year-old bare-root seedlings of the pioneer species *Mytilaria laosensis*, *Castanopsis hystrix* and *Betula alnoides*, planted into holes 0.6 m × 0.6 m × 0.35 m deep in small monocultural patches. Seedlings are planted in spring, ideally on cloudy days after rain.

Tending. Tending involves clearing competing vegetation from around the seedlings (to a radius of 0.8–1.0 m), with the cut weeds then acting as mulch to retain soil moisture, reduce the growth of new weeds and provide nutrition as they decompose; the soil is also loosened to encourage water infiltration. Seedlings are tended twice a year (in March/April and July/August) for the first three years, although some sites with a high density of competing vegetation may require additional tending (in September/October).

The site is tended again in year 8 to remove vines, dead wood and withered, damaged or sick trees. A first thinning is conducted at year 10 to remove 40 percent of the pioneer tree stock. At year 15, a second thinning is conducted to remove 50 percent of the remaining trees. A third thinning is conducted at year 20; depending on the attributes of the various tree species, the intensity of this thinning could be 50–70 percent, to achieve a final density of 300–375 trees per ha.

At year 20, high-value shade-tolerant tree species are interplanted in the understorey of the pioneer species at a density of 4 m × 5 m (450–600 seedlings per ha), evenly or randomly spaced, depending on species' configurations and proportions. Suitable species for this interplanting include *Manglietia hainanensis*, *Mesua ferrea*, *Michelia macclurei*, *Paramichelia baillonii* and *Tectona grandis*. The shade-tolerant species are planted in holes 0.6 m × 0.6 m × 0.35 m deep; the newly planted seedlings are tended for the first three years, as in the method described above for the pioneer species. After the first three years they are allowed to grow naturally, with no interventions.

Proposed future management regime. A selective cutting regime will be applied to the forest as the trees mature. At year 40–50, trees with a dbh of 50 cm or greater will be harvested. Care is needed to minimize damage to the stand during harvesting – a cable yarding system tested in the experimental forest in 2012 caused little damage to the remaining trees. After the first selective harvesting, there will be no more plantings. Natural regeneration will emerge through the gaps created by harvesting and become the new generation of canopy trees, to be managed as potential crop trees. Thus, a semi-natural forest will be created, with the potential for sustainable management.

Current status

After 30 years, the biodiversity at the experimental site has increased and diverse plant communities have formed. The average dbh of 30-year-old trees is 28–35 cm, average height is 18–25 m and the standing volume is 420–625 m^3 per ha. Average annual dbh increment is 1.1 cm and average annual height increment is 0.8 m.

The forest has developed into a natural succession state and forest trees are regenerating naturally – especially *Castanopsis hystrix*, *Erythrophleum fordii*, *Michelia macclurei* and *Mytilaria laosensis*. In 2012, naturally established *Castanopsis hystrix* seedlings, for example, were present at the site at a density of about four seedlings per m^2 and a height of 0.25–1.50 m.

[1] The discussion in this section is derived from various sources, including ECTF research. It provides a general overview of the ECTF approach to the restoration of degraded subtropical forests but is not meant to be comprehensive.

Naturally established *Mytilaria laosensis* seedlings were present at a density of five seedlings per m^2 and a height of 0.2–2.5 m. This forest restoration approach, therefore, is facilitating an increase in biodiversity and helping to stabilize the ecosystem, restore environmental services and improve forest productivity and economic value. It has become a leading example of the restoration of degraded natural forests in China's subtropics.

CONCLUSION

The scale of China's forest plantation programme is unprecedented globally. Despite the programme's overall success, however, it is clear that China's new forests face significant challenges. Growing trees in monocultures may be a financially efficient way of producing wood, but such plantations are vulnerable to pests, diseases and changing environmental conditions, and second and subsequent generations often decline in productivity. There is an urgent need to find more sustainable approaches that ensure the long-term productivity and resilience of the new forests while also meeting economic, social and environmental needs.

Close-to-nature forestry makes strong environmental sense. It aims to use natural processes to the greatest extent possible and to build ecological resilience by encouraging diversity – in the number of species, in forest structure, and across landscapes. Over time, close-to-nature forestry improves ecological functions, reduces soil erosion, and improves water quality and the scenic value of landscapes. More research is required into costs and benefits to ensure that the approach meets economic goals. The signs are positive, however, given the very high prices that can be obtained for the species being grown and the potential for conducting a wide range of income-generating activities in the growing forests.

The experimental designs described in this article, and other designs (including those for *Eucalyptus* plantations) offer a potential means for transforming China's vast monocultural plantations into close-to-nature forests that provide economic returns and ultimately create a very-high-value resource. Encouraged by the ECTF's success, all twelve major forest experimental centres in China are now pursuing similar research with the aim of developing close-to-nature forestry to suit conditions in other biogeographic regions and landscapes in China. The ECTF's approach could also be applied elsewhere in tropical and subtropical Asia. ◆

References

FAO. 2010. *Global forest resources assessment*. Main report. FAO Forestry Paper No. 163. Rome.

ITTO. 2002. *Guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests*. International Tropical Timber Organization, Yokohama, Japan.

Küchli, C. 2013. The Swiss experience in forest sustainability and adaptation. *Unasylva*, 64(240): 12–16.

State Forestry Administration. 2014. *Eighth national forest inventory*. Beijing, China.

Yu, X., Bai, X., Xu, D. & Chai, J. 1999. Nutrient cycle of Eucalyptus plantations with different continuous-planting rotations. *Chinese Journal of Tropical Crops*, 20(3): 60–66.

A comprehensive account of the ECTF's close-to-nature experimental designs was published recently by the Asia–Pacific Network for Sustainable Forest Management and Rehabilitation. ◆

After 30 years of restoration, degraded land is covered by various broadleaved species planted in patches at the Baiyun Forest Farm, Experimental Center of Tropical Forestry

© EXPERIMENTAL CENTER OF TROPICAL FORESTRY


© AGS-CTFC

Forest landscape restoration experiences in southern Europe: sustainable techniques for enhancing early tree performance

J. Coello, J. Cortina, A. Valdecantos and E. Varela

It is crucial to raise awareness about the goods and services that forests provide, and the risks that they face in an increasingly harsh climate, in order to boost support for restoration programmes in southern Europe.

Jaime Coello is Forest Engineer and Researcher, Sustainable Forest Management Unit, Forest Sciences Centre of Catalonia (CTFC), Spain.
Jordi Cortina is Professor, Department of Ecology and Multidisciplinary Institute for Environmental Studies, University of Alicante, Spain.
Alejandro Valdecantos is Senior Researcher, Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM), Valencia, Spain.
Elsa Varela is Researcher, Mediterranean Regional Office of the European Forest Institute (EFIMED), Barcelona, Spain.

THE SOUTHERN EUROPEAN CONTEXT

Southern Europe is a region of great ecological variety, with 13 out of a total of 21 European bioclimates (Rivas-Martínez *et al*., 2004), owing to its combination of a wide range of physical conditions, uneven relief and complex land-use history (Vallejo *et al*., 2012a).[1] The Mediterranean area, in which southern Europe is situated, is one of the world's 25 biodiversity hotspots (Palahí *et al*., 2008), i.e. an area characterized by both exceptional levels of plant endemism and serious habitat loss, and which therefore merits significant conservation efforts.

A distinctive feature of southern Europe is its Mediterranean climate, with mild wet winters and hot dry summers. Another key feature of this area is its history of intense human activity, spanning millennia. The resulting cultural landscapes are rich but have been subjected to episodes of major environmental degradation, mainly due to the conversion of forests for agriculture or grazing land and the overexploitation

[1] For the purposes of this article, southern Europe is considered to refer to the Mediterranean areas of the Balkans, France, Italy, Portugal, Spain and Turkey, as defined by Vallejo *et al*. (2012a).

Above: Aleppo pine planted with soil conditioner and yute mulch in semiarid conditions

of forest resources. This has been further exacerbated by the slow recovery rate of ecosystems, linked to limited and uneven water availability as well as to natural and human-induced forest fires. These factors have resulted in predominantly low profitability from the management of these ecosystems and a lack of commercial interest in their restoration, which tends to rely on funding from public and non-profit organizations.

Over the past decades, land use has become polarized. The least productive and hardest-to-access areas have witnessed the abandonment of agricultural, livestock and forestry uses. As a result, the traditional mosaic pattern of land use is being replaced by more homogeneous landscapes, where forest vegetation rapidly colonizes abandoned fields. Between 1990 and 2000, Spain, Italy and France showed an annual net gain in forest area of 2.1, 1.0 and 0.6 percent respectively, ranking them among the ten countries in the world with the highest increase in forest surface area (FAO, 2010). Most of the resulting ecosystems are structurally imbalanced (most trees being of the same age) and overly dense (growth halted due to competition), and show low vigour and poor regeneration capacity, which results in low resilience when faced with disturbances.

On the other hand, easily accessible areas and lowlands have seen a significant intensification of uses, boosted by economic development and European Union (EU) support in the last three decades. Many traditionally poor regions have launched programmes to support agricultural intensification (such as irrigation and greenhouses) and livestock production, and southern EU countries are now the primary suppliers of fruit and horticultural products to central and northern Europe (EU, 2014). Other activities that have expanded over recent years include housing development and tourism, which have become major economic pillars for most southern European regions. The population in southern Europe is increasingly concentrated in urban areas, especially in coastal regions (Grove and Rackham, 2003). These changes and this increase in wealth come at a cost: the Mediterranean region, especially southern Europe, has an important ecological deficit, i.e. the difference between the ecological footprint consumption (area of biologically productive land and water required to produce the goods consumed and to assimilate the waste generated) and the real capacity of these ecosystems. This imbalance rose by 230 percent between 1961 and 2008 (GFN, 2012). The combined impact of these pressures has led to severe environmental degradation at local levels and continuous or seasonal overuse of resources, notably water (Daliakopoulos and Tsanis, 2013).

The forests in southern Europe are widely recognized for their multifunctionality in terms of the production of goods (i.e. timber, biomass, cork, edible nuts, medicinal and aromatic plants, honey, game, resin) and services (i.e. hydrological regulation, water quality, soil and biodiversity protection, recreation, landscape). Different studies have estimated that non-wood forest products (NWFP) account for more than 40 percent of the total economic value of forests in the Mediterranean areas (Merlo and Croitoru, 2005). In addition, growing demand for amenities and social services, and recognition of forests' role in the protection of water and soil, demonstrates the importance of the non-market dimension of forests, and could boost the valorization of those ecosystems, promoting their conservation.

The type of forest ownership has important implications for the use and conservation of these forests. In southern Europe, more than 60 percent of forests (98 percent in the case of Portugal [FAO, 2010]) are privately owned (FOREST EUROPE, UNECE and FAO, 2011) with very fragmented estates, e.g. in Portugal, 85 percent of forest holdings are smaller than 5 ha (FOREST EUROPE, UNECE and FAO, 2011). The lack of economic profitability and of targeted incentives to promote active ownership makes it difficult to set up shared forest management or restoration plans. This also results in unintended negative effects, including increased fire risk leading to marketable (e.g. forest products, infrastructure) and non-marketable (e.g. biodiversity, landscape quality) losses, and a larger dependence on non-renewable materials.

FOREST LANDSCAPE RESTORATION IN SOUTHERN EUROPE

Forest landscape restoration (FLR) is a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes (WWF and IUCN, 2000). This approach has been identified as an ideal basis for the management of Mediterranean terrestrial ecosystems, due to its focus on the restoration of landscape functionality, its holistic approach, and its combination of production- and conservation-related objectives (Soutsas *et al.*, 2004).

As mentioned above, southern Europe has witnessed a significant increase in forest area since the 1990s, often linked to the abandonment of agriculture and grazing and the resulting colonization of open areas or encroachment of forest areas with sparse vegetation (Abraham *et al.*, 2014). However, reforestation and afforestation initiatives have also contributed to this increase. Two countries on the northern rim of the Mediterranean (Turkey and Spain) rank among the top ten countries of the world for afforested area, with 87 300 and 30 461 ha yr^{1}, respectively in 2003–2007 (FAO, 2010). The most common types of FLR initiatives in the last decades have been linked to restoration after forest fires, prevention of land degradation, combating desertification, and the afforestation of former agricultural land.

Restoration after forest fires has been particularly relevant in Portugal and Spain, where burned area represented 45 percent of the total area affected by forest fires in Europe in 1960–2000 (Schelhaas *et al.*, 2003); the trend continued in the following decade, with 2 million ha burned only in Portugal between 2000 and 2013 (Schmuck *et al.*, 2014). Greece and the western

Balkan countries have also suffered from severe forest fires in the past decades.

Land degradation is a common problem in most southern European areas, being especially relevant in those with limited water availability, as a result of their slow recovery rates, whether due to natural phenomena – such as low rainfall and high evapotranspiration rates – or human causes – such as overuse of groundwater resources and salinization from improper agricultural techniques (Gunal, 2014).

Countries such as Turkey and Spain have launched long-term programmes for combating desertification, such as, respectively, the Eastern Anatolia Watershed Rehabilitation Project since 1993 (Cevik *et al*., 1999) and the LUCDEME Project (LUCha contra la DEsertificación en el MEditerráneo) since 1981 (MAGRAMA, 2015).

Finally, afforestation of agricultural land has been the main type of forest restoration carried out in the southernmost countries (Greece, Italy, Portugal and Spain) of the EU since the implementation of the EU's Common Agricultural Policy measures (1992–1999) and other EU rural development policies (from 2000 onwards).

The main factors that will shape FLR opportunities in southern Europe in the short and medium term concern financial constraints, climate change and EU environmental and research policies.

As mentioned before, the funding of FLR activities in southern Europe cannot rely solely on economic returns on investment, but depends instead on ecosystem services that are often non-marketable. Thus, public investment may be essential to ensure the implementation of FLR. The availability of national funds in most southern European countries has been particularly limited since the beginning of the economic crisis, which has had a major impact on the economies of these countries and, in turn, on the implementation of large-scale restoration projects. At present, many reforestation activities, generally on a small scale, are performed with the financial and logistical support of non-governmental organizations (NGOs) and volunteers.

The Mediterranean basin is regarded as one of the areas most vulnerable to climate change (IPCC, 2007a, 2007b; Regato, 2008; Vayreda *et al*., 2012). This includes a rise in temperature, together with a decrease in precipitation and shifts in its seasonal distribution, and more frequent

Ecosystem degradation after human-induced forest fires, Sierra de Chiva, Valencia, Spain

© ANDY MCGEENEY

Forest landscape restoration on marginal agricultural land, Avinyo, Barcelona, Spain

extreme events (torrential rains and droughts). This may dramatically affect the provision of goods and services from forest ecosystems, including the regulation of the water cycle, carbon storage, delivery of wood and non-wood products and a wide range of other services in the medium and long term (FAO, 2013). Overall, climate change is likely to reduce the ability of Mediterranean forests to withstand disturbances such as increased frequency and severity of pathogen outbreaks, wildfires and drought (FOREST EUROPE, UNECE and FAO, 2011). The mainstreaming of the need for climate change action, including mitigation policies and initiatives at all levels, represents a significant opportunity for the development and implementation of further FLR initiatives in southern Europe.

Finally, the EU's environmental and research policies pay special attention to climate-related issues for the period 2014–2020. In the case of FLR, there is a specific funding call in Horizon 2020 under the topic "More effective ecosystem restoration in the EU", which represents an opportunity to move forward in the prioritization of target systems using landscape restoration's holistic approach. Another major EU programme related to FLR is the commitment to restore, by 2020, 15 percent of degraded land in Europe, an initiative launched by the UN's Convention on Biological Diversity (CBD).[2]

TECHNICAL APPROACH TO FLR IN SOUTHERN EUROPE

The technical approach to FLR in southern Europe is based on specific constraints.

Main constraints for FLR in southern Europe

The most relevant constraints for FLR in southern Europe include socioeconomic, biotic and abiotic factors:

Economic: The predominantly poor cost–benefit ratio of FLR (in economic terms) makes it largely dependent on public funding, whose main aim for FLR is the provision of ecosystem services (Vallejo *et al*., 2012b). The main economic constraints are:

- low productivity, which discourages private initiative;
- difficult access: it may be expensive to mechanize interventions, e.g. in the case of steep slopes, sparse and/or low-quality road networks;
- relatively high labour costs compared to the southern rim of the Mediterranean basin.

Social: Infrequent social involvement in FLR (definition of targets, support to implementation and monitoring), which limits the opportunities for implementing FLR close to populated areas.

---

[2] According to the CBD definition, "A degraded forest is a secondary forest that has lost, through human activities, the structure, function, species composition or productivity normally associated with a natural forest type expected on that site. Hence, a degraded forest delivers a reduced supply of goods and services from the given site and maintains only limited biological diversity. Biological diversity of degraded forests includes many non-tree components, which may dominate in the undercanopy vegetation." (https://www.cbd.int/forest/definitions.shtml)

TABLE 1. Main techniques applied to promote the successful establishment of trees and shrubs within FLR in southern Europe

Action	Technique	Description
Techniques for increasing water and soil availability (especially relevant at drier sites)		
Action	**Technique**	**Description**
Soil preparation	Water harvesting	Modify soil profile in the area around the tree to promote runoff concentration and storage: it can be complemented by an impermeable area to concentrate runoff and/or a highly permeable area (column of stones or dry well) immediately upslope of the seedling to enhance water infiltration
	Deep/large plantation pits	Deep soil preparation (soil ripping, pit excavation: 60–90 cm) for enhancing water retention and promoting root growth
Watering	Irrigation with water wagons/drippers	Application of water from deposits, water wagons or reservoirs, directly on the plant or through partially buried tubes
Adapted/ improved forest reproductive material/ stock and techniques	Use of well-adapted planting stock	Native species from local provenances; seedlings of good physiological and genetic quality
	Mycorrhized seedlings	Use of seedlings incorporating a specifically chosen mycorrhizal (plant and fungi) association that fosters water and nutrient uptake
	Promotion of functional diversity	Use of a variety of species with different characteristics (sprouters and seeders, deep-rooters and shallow-rooters, N-fixing species)
	Direct sowing	Use of seeds instead of seedlings to reduce costs
	Optimization of planting/sowing time	Planting and sowing when moisture availability and temperature are optimal for plant growth
Soil fertility amelioration	Soil conditioners with hydro-absorbent polymers	Granulated product mixed with the soil in the plantation pit, absorbing the excess of water after rain, retaining it and releasing it progressively; other ingredients of the soil conditioner include fertilizers and root-growth stimulators
	Soil fertilizers and amendments	Enhancing soil fertility with slow-release fertilizers and organic amendments
FLR implementation, considering microsite conditions	Working scale: microsite	Implementing FLR in optimal microsites, such as those accumulating runoff water. In drylands, it may be beneficial to plant near pre-existing nurse plants, i.e. herbs or shrubs that can protect the seedling against excessive radiation, nutrient scarcity and predation during the first years
Techniques to control competing vegetation (especially relevant at wet sites)		
Action	**Technique**	**Description**
Chemical weeding	Herbicides	Application of herbicides to suppress weeds, provided that no environmental or legal constraints apply; recurrent intervention
Mechanical weeding	Mechanical weeding	Manual or tractor-operated weeding; recurrent intervention with the risk of damaging the installed trees or shrubs
Mulching	Plastic film mulching	Flexible sheet or mat installed in the soil around the tree to suppress competing vegetation; one-time application, effective to increase soil water retention; requires removal
	Biodegradable film mulching	Biodegradable cover (bioplastic, plant fibre); outcomes similar to plastic films, higher purchase cost but the cover does not require removal
	Particle mulching	Mulching soil with a layer of organic (agricultural or forest waste: straw, chips …) or inorganic (stones) pieces. Similar effect to film mulches, with the possibility of recovering organic waste
	Living mulch	Seeding the soil around the tree with desired species, avoiding the spontaneous establishment of weeds; requires good knowledge of site, plant ecology and plant–plant interactions
Silvicultural techniques	High density	Utilization of high initial sowing or planting densities, preferably of a range of species, to promote early canopy closure; self-maintaining technique, suitable in rich sites
Techniques against browsing damage		
Action	**Technique**	**Description**
Areal protection	Fence	Closing the perimeter with a physical barrier, made of metal mesh or with lines plugged to an electricity generator
	Chemical repellent	Commercial or homemade repellents that can have a chemical function (e.g. human hair), recurrently applied
Individual protection	Solid-walled shelter	Shelter (preferably ventilated) with greenhouse effect: higher maximum temperature, lower irradiance and exposure to desiccating wind
	Meshed shelter	Cylinder-shaped mesh, with low or negligible greenhouse effect to avoid excessive seedling slenderness and heat damage
Silvicultural techniques	Hiding/repelling species	Preferably in high plantation densities: utilize species that limit the access of wildlife (thorny, unpalatable)

Sources: Mansourian *et al*., 2005; Chirino *et al*., 2009; Coello *et al*., 2009; Oliet and Jacobs, 2012; Vallejo *et al*., 2012b; Piñeiro *et al*., 2013; Stanturf *et al*., 2014.

Availability of soil resources, including water: Low annual precipitation levels may conceal high year-on-year and seasonal variability, with drought often followed by torrential rain. This climate regime affects vegetation directly, because of water shortage, resulting in loss of growth and vigour and consequent risk of death. Moreover, there are indirect effects on the ecosystem: high forest fire risk and slow soil development, which is affected by erosion and by the poor rate of soil organic matter accumulation. The resulting soils, predominantly thin, have poor fertility (Pausas *et al*., 2004) and low water-retention capacity. This factor is especially critical in areas with low precipitation and negative physiography (e.g. steep slope or convex shape).

Competing vegetation: Spontaneous and often unwanted grasses may compete with the desired (i.e. planted or sown) vegetation for water, light and nutrients, ultimately hampering their survival and growth (Willoughby *et al*., 2009). Competition may be especially intense at the wettest sites.

Browsing damage: Domestic and wild herbivores may compromise the success of sowing or planting and in turn the survival and growth of the resulting vegetation. Growing populations of deer, roe deer and wild boar in the wettest areas (Van Lerberghe, 2014) and of rabbit and hare in drier ones represent a major challenge for sustainable FLR.

Local limitations: Specific areas may present additional limitations, e.g. thin soils, a high proportion of soil volume consisting of stones and rocks, high carbonate or active limestone content, or alkaline soils.

FLR solutions in southern Europe

Experience with FLR in southern Europe has enabled the development of a range of technical solutions to promote the successful establishment of trees and shrubs and favour their survival and resilience. The most common techniques used to overcome the biotic and abiotic constraints mentioned above, which are particularly critical during the first years of the restoration, are shown in Table 1.

APPLICATION AND DEVELOPMENT OF INNOVATIVE FLR TECHNIQUES

Two relevant forest restoration initiatives in southern Europe are presented below.

Bridging effectiveness and sustainability in afforestation/reforestation in a climate change context: new technologies for improving soil features and plant performance (SustAffor Project [FP7-2013-SME-606554]), 2013–2015

The project's main objective is to conceive, produce, develop and validate in the field novel techniques that aim to improve afforestation/reforestation projects from an environmental, technical and economic point of view, and to explore the synergies between them, in a wide range of ecological conditions representative of southern Europe. These novel techniques include:

- A new generation of soil conditioners, including a new hydro-absorbent polymer in an improved mixture. The aim is to diminish post-planting stress and to increase soil water availability during dry periods.
- Innovative mulching products: (i) fully biodegradable framed bioplastic mulch, based on a new biopolymer formula, fused to a flexible bioplastic sheet; (ii) fully biodegradable semi-rigid bioplastic mulch, based on a new biopolymer formula; (iii) fully biodegradable mulch made with woven jute cloth, treated with furan bio-based resin for increased durability; and (iv) a long-lasting mulching mat, based on recycled rubber (worn-out tyres, conveyor belts), reusable in successive tree planting projects. The biodegradable mulches are intended to become an alternative to plastic mulching, being more environmentally friendly and not requiring removal. The long-lasting rubber mulch aims to re-use industrial waste, a promising technique, especially for restoration in urban environments.

These techniques are evaluated, individually and in combination, and are compared to reference techniques (i.e. commercial soil conditioner, plastic mulching and herbicide application) in eight field trials distributed across a range of climatic conditions in northeastern Spain, representative of the main bioclimates in southern Europe: semiarid (*BS – Steppe climate cold*, according to the Köppen climate classification), Mediterranean continental (*Csb – Temperate, dry mild summer*), Mediterranean humid (*Cfb – Maritime temperate*), and montane (*Cfc/Dfb – Temperate/Continental*). The field trials in semiarid (with Aleppo pine, *Pinus halepensis*) and montane (with ash – *Fraxinus excelsior* and birch – *Betula pendula*) conditions represented typical protective forest restoration interventions promoted by public entities in steep-sloped, hard-to-access areas. Field trials in Mediterranean continental and humid conditions consist of productive plantations and are commonly carried out by private actors in the framework of afforestation of small agricultural fields: species include hybrid walnut (*Juglans x intermedia*) for valuable timber production, holm oak (*Quercus ilex*) with mycorrhizal inoculation of black truffle (*Tuber melanosporum*), and stone pine (*Pinus pinea*) for nut production.

The effects of the different techniques, alone and combined, in a total of 17 treatments per field trial, were assessed at three levels:

- tree: survival, diameter and height growth, physiology (water-related variables) and biomass allometry (above-ground and below-ground);
- soil: effects of the trees on the most important parameters related to soil fertility and biochemical changes in soil organic matter;
- environmental conditions at micro-site level: soil moisture and temperature.

The project consortium is composed of ten entities from four countries, including four small and medium enterprises (SMEs) developing novel techniques (DTC, EcoRub, La Zeloise, TerraCottem Internacional), two SMEs commercializing FLR products (Terrezu, Ceres International) and four research and development (R&D) centres (CTFC – project coordinator, Centre national de la recherche scientifique (CNRS), Centexbel and Edma Innova).

The preliminary results, after two years of field experience, suggest that innovative soil conditioners have a significantly positive impact at the sites characterized by poor soils, with low water and nutrient retention capacity (semiarid and montane). Mulching, either with innovative or traditional materials, is an excellent option for extensive management of forest plantations at productive sites (Mediterranean continental and humid).

Albatera demonstration project

Demonstration projects implement techniques that have proven successful in small-scale experiments and pilot projects, and are an excellent tool for disseminating best practices. A demonstration project for restoring degraded semiarid areas was established in the Sierra de Albatera, southeastern Spain, in 2002, based on collaboration between public administrations (Dirección General de Conservación de la Biodiversidad, Ministerio de Agricultura, Alimentación y Medio Ambiente; Conselleria de Infraestructuras, Territorio y Medio Ambiente, Generalitat Valenciana), CEAM, the University of Alicante and the Centro de Investigaciones sobre Desertificación (CSIC-CIDE) (Vilagrosa *et al.*, 2008).

The area concerned is highly vulnerable to desertification due to its semiarid climate, with scarce but torrential rainfall and high summer temperatures, the presence of highly erodible soils and rough topography. This vulnerability is also a result of its land-use history, including intensive harvesting for fuelwood and fibre, and grazing. After abandonment, in the mid-twentieth century, spontaneous recovery was scarce, and the planting of *Pinus halepensis* often met with limited success. Terraces aimed at improving pine establishment often had the opposite effect, as they frequently reduced topsoil fertility, and, despite concentrating runoff, led to further sediment transport and erosion. Large areas of the 25-ha catchment were severely disturbed by a water pipe and a dense network of unpaved roads.

After an initial diagnosis, the project identified four major objectives: (1) to reinstate catchment functionality by establishing vegetation patches and restoring their key role in water, carbon, sediment and nutrient cycles, and facilitating their positive impact on community assembly (arrival of new species in the ecosystem); (2) to increase biodiversity, and resistance and resilience to future disturbances and sources of stress; and (3) to prevent further site degradation by reducing the risk of erosion and downstream flooding.

In accordance with the diagnosis and the objectives defined above, five strategic areas were identified:

1. a detailed examination of the current situation and potentialities, including the spatial definition of uniform intervention units;
2. selection of different sets of autochthonous woody species suited to each unit, maximizing their capacity for protecting the soil and recovering after disturbance;
3. use of high-quality seedlings adapted to harsh environmental conditions;
4. application of best planting techniques, adapted to each unit, including deep planting holes, micro-watersheds to concentrate runoff, organic amendments, organic and stone mulches, and tree shelters;
5. implementation of an efficient evaluation and monitoring plan.

The project was successful, as it allowed the establishment of key woody species in the area, responding to the original objectives, and facilitated the dissemination of good restoration practices. Guided visits have been conducted for over 500 visitors, including practitioners, postgraduate students, researchers and lecturers from dryland areas worldwide. Project design and results have been the subject of numerous lectures, conferences and workshops. In addition, the area has been used for further research projects (e.g. FUNDIVFOR [Interacciones entre funcionalidad y diversidad en ecosistemas semiáridos degradados y su relación con las actividades de reforestación] and PRACTICE [Prevention and Restoration Actions to Combat Desertification. An Integrated Assessment]).

CONCLUSIONS AND LESSONS LEARNED

FLR is expected to continue to be fundamental for restoring degraded ecosystems and ensuring the provision of crucial services in southern Europe. Because of the generally slow dynamics of ecosystems, and their level of human intervention, active restoration is expected to be the preferred approach.

The low commercial interest in FLR in southern Europe makes it necessary to identify innovative funding mechanisms, building on social concern about the importance of preventing land degradation.

In the framework of current and future challenges, notably climate change and the associated increased severity of drought and fires, the ongoing experimental field trials in southern Europe will serve as a fundamental infrastructure to pilot the migration of techniques from drier areas to wetter areas, both within and beyond the region.

© ALEJANDRO VALDECANTOS

Shrub restoration, water harvesting and multiple seedling planting in semiarid conditions, Sierra de Albatera, Alicante, Spain

Forest landscape restoration on agricultural land, Pontos, Girona, Spain

© AGS-CTFC

Due to uncertainty regarding future environmental conditions and the long lifespan of FLR projects, a conservative and adaptive management approach is recommended. Techniques for successful FLR in southern Europe should be:

- cost-effective throughout the full life cycle (production, transport, installation/execution/application, disposal) and requiring minimal labour investment;
- resilient: effective in the short and medium term and applicable in a range of conditions; self-sustained and in synergy with natural processes and with other restoration techniques;
- environmentally friendly: respectful of the environment during the whole life cycle.

Research and knowledge transfer are fundamental steps in the development and application of best practices and for raising social awareness about the importance of FLR.

Acknowledgements

The research leading to the Sustaffor results received funding from the EU's Seventh Framework Programme managed by the REA-Research Executive Agency http://ec.europa.eu/research/rea (FP7/2007-2013) under grant agreement no. 606554.

J. Cortina's research is funded by the project UNCROACH (Spanish Ministry of Science and Innovation): CGL2011-30581-C02-01. ◆

References

Abraham, E.M., Evelpidou, N. & Kyriazopoulos, A. 2014. *The present state of restoration in Greece*. Desert Restoration Hub, ES1104 Action COST, 5th MC Meeting. Timisoara, Romania.

Cevik, B., Cetin, M. & Kusek, G. 1999. *Eastern Anatolia Watershed Rehabilitation Project*. Paper presented at the 9th International Rainwater Catchment Systems Conference. Petrolina, Brazil.

Chirino, E., Vilagrosa, A., Cortina, J., Valdecantos, A., Fuentes, D., Trubat, R., Luis, V.C., Puértolas, J., Bautista, S., Baeza, M.J., Peñuelas, J.L. & Vallejo, R. 2009. Ecological restoration in degraded drylands: the need to improve the seedling quality and site conditions in the field. *In* S.P. Grossberg, eds. *Forest Management*, pp. 85–158. Hauppage, NY, USA, Nova Science Publishers, Inc.

Coello, J., Piqué, M. & Vericat, P. 2009. *Producció de fusta de qualitat: plantacions de noguera i cirerer: aproximació a les condicions catalanes – guia pràctica*. Barcelona Generalitat de Catalunya, Departament de Medi Ambient i Habitatge, Centre de la Propietat Forestal.

Daliakopoulos, I.N. & Tsanis, I.K. 2013. *Historical evolution of dryland ecosystems*. CASCADE Project Deliverable 2.1. Cascade Reports series. Crete, Greece, Technical University of Greece.

EU. 2014. *Eurostat regional yearbook 2014*. Luxembourg, Publications Office of the European Union (available at http://ec.europa.eu/eurostat/documents/3217494/5785629/KS-HA-14-001-EN.PDF/e3ae3b5c-b104-47e9-ab80-36447537ea64).

FAO. 2010. *Global Forest Resources Assessment: Main Report*. FAO Forestry Paper No. 163. Rome.

FAO. 2013. *State of Mediterranean Forests*. Rome.

FOREST EUROPE, UNECE & FAO. 2011. *State of Europe's Forests 2011. Status and trends in sustainable forest management in Europe*. Aas, Norway, FOREST EUROPE, UNECE & FAO.

GFN (Global Footprint Network). 2012. *Mediterranean Ecological Footprint trends*. Châtelaine, Switzerland, GFN (available at http://www.footprintnetwork.org/images/article_uploads/Mediterranean_report_FINAL.pdf).

Grove, A.T. & Rackham, O. 2003. *The nature of Mediterranean Europe. An ecological history*. New Haven, Conn., USA, Yale University Press.

Gunal, H. 2014. *Land degradation/desertification and examples of studies on combating land degradation/desertification in Turkey*. Desert Restoration Hub, ES1104 Action COST, 5th MC Meeting. Timisoara, Romania.

IPCC. 2007a. *The physical science basis. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Climate Change 2007 Vol. 1. Cambridge, UK and New York, USA, Cambridge University Press.

IPCC. 2007b. *Climate Change 2007: synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, IPCC.

MAGRAMA. 2015. *LUCDEME project* (available at http://www.magrama.gob.es/es/desarrollo-rural/temas/politica-forestal/desertificacion-restauracion-forestal/lucha-contra-la-desertificacion/lch_lucdeme.aspx). Accessed March 2015.

Mansourian, S., Lamb, D. & Gilmour, D. 2005. *Overview of technical approaches to restoring tree cover at the site level. In* S. Mansourian, D. Vallauri and N. Dudley, eds. *Forest restoration in landscapes: beyond planting trees*. New York, USA, Springer (in cooperation with WWF International).

Merlo, M. & Croitoru, L. 2005. *Valuing Mediterranean forests. Towards a total economic value*. Wallingford, UK, CABI International.

Oliet, J. & Jacobs, D.F. 2012. Restoring forests: advances in techniques and theory. *New Forests*, 43(5): 535–541.

Palahí, M., Mavsar, R., Gracia, C. & Birot, Y. 2008. Mediterranean forests under focus. *International Forestry Review*, 10(4): 676–688.

Pausas, J.G., Blade, C., Valdecantos, A., Seva, J.P., Fuentes, D., Alloza, J.A., Vilagrosa, A., Bautista, S., Cortina, J. & Vallejo, R. 2004. Pines and oaks in the restoration of Mediterranean landscapes of Spain: New perspectives for an old practice – a review. *Plant Ecology*, 171(1): 209–220.

Piñeiro, J., Maestre, F.T., Bartolomé, L. & Valdecantos, A. 2013. Ecotechnology as a tool for restoring degraded drylands: A meta-analysis of field experiments. *Ecological Engineering*, 61: 133–144.

Regato, P. 2008. *Adapting to global change: Mediterranean Forests*. Malaga, Spain, IUCN Centre for Mediterranean Cooperation.

Rivas-Martínez, S., Peñas, A. & Díaz, T.E. 2004. *Bioclimatic map of Europe – Thermoclimatic belts* (available at http://www.globalbioclimatics.org/form/tb_med.jpg). Accessed 27 March 2015.

Schelhaas, M., Nabuurs, G. & Schuck, A. 2003. Natural disturbances in the European forests in the 19th and 20th centuries. *Global Change Biology*, 9(11): 1620–1633.

Schmuck, G., San-Miguel-Ayanz, J., Camia, A., Durrant, T., Boca, R., Libertà, G., Petroliagkis, T., Di Leo, M., Rodrigues, D., Boccacci, F. & Schulte, E. 2014. *Forest fires in Europe, Middle East and North Africa 2013*. Luxembourg, European Commission Joint Research Centre.

Soutsas, K.P., Papageorfiou, A.C., Tampakis, S., Arabatzis, G. & Kasimiadis, D. 2004. The concept of Forest Landscape Restoration in the Mediterranean Basin. *New Medit*, 3(4): 57–62.

Stanturf, J.A., Palik, B.J. & Dumroese, R.K. 2014. Contemporary forest restoration: A review emphasizing function. *Forest Ecology and Management*, 331: 292–323.

Vallejo, R., Allen, E.B., Aronson, J., Pausas, J.G., Cortina, J. & Gutiérrez, J.R. 2012a. Restoration of Mediterranean-type woodlands and shrublands. *In* J. van Andel & J. Aronson, eds. *Restoration ecology: the new frontier*, pp. 193–207. Oxford, Wiley-Blackwell.

Vallejo, R., Smanis, A., Chirino, E., Fuentes, D., Valdecantos, A. & Vilagrosa, A. 2012b. Perspectives in dryland restoration: approaches for climate change adaptation. *New Forests* 43(5): 561–579.

Van Lerberghe, P. 2014. *Technical guide: protecting trees against browsing damage – Mesh-walled tree shelters*. Paris, CNPF-IDF.

Vayreda, J., Martinez-Vilalta, J., Gracia, M. & Retana, J. 2012. Recent climate changes interact with stand structure and management to determine changes in tree carbon stocks in Spanish forests. *Global Change Biology*, 18(3): 1028–1041.

Vilagrosa, A., Chirino, E., Bautista, S., Urgeghe, A., Alloza, J.A. & Vallejo, V.R. 2008. Proyecto de demostración de lucha contra la desertificación: regeneración y plan de manejo de zonas semiáridas degradadas en el T.M. de Albatera (Alicante). *Cuadernos de la Sociedad Española de Ciencias Forestales*, 28: 317–322.

Willoughby, I., Balandier, P., Bentsen, N.S., McCarthy, N. & Claridge, J., eds. 2009. *Forest vegetation management in Europe: current practice and future requirements*. Brussels, COST Office.

WWF & IUCN. 2000. *Forests reborn: A workshop on forest restoration*. WWF and IUCN (available at https://cmsdata.iucn.org/downloads/flr_segovia.pdf). ◆

Bamboo: the opportunities for forest and landscape restoration

C. Rebelo and K. Buckingham

© ECOPLANET BAMBOO

A fresh look at bamboo's potential in tackling restoration challenges and improving resilience to climate change.

Camille Rebelo is Co-founder of EcoPlanet Bamboo.
Kathleen Buckingham is Research Associate with the World Resources Institute.

In forestry circles, bamboo is not always given the credit it deserves. And yet, with adequate attention, investment, and standards, bamboo could play a prominent role in forest and landscape restoration and become a major renewable and sustainable crop (Buckingham, 2014a). Perceptions of a natural resource often shape its usage. In this case, bamboo's sometimes unfortunate image is linked to European notions of landscape, plant value and utility. For example, the advent of modern agriculture and modern forest management during the eighteenth and nineteenth centuries influenced the European approach to plant management. Forests became valued as "timber", while other plants were considered to be either "crops" (valuable plants) or "weeds" (unwanted plants) (Scott, 1998). To this day, bamboo, stuck somewhere between forestry, horticulture and agriculture, defies any attempt at neat categorization, and international forestry institutions still tend to overlook it as an important natural resource (Buckingham, 2014a). In recent times, bamboo has been associated with the "alternative" green movement. Entrenched in hippy stereotypes, its image has not translated well in financial markets. However, as institutional investment in forestry hits the US$ 100 billion mark (New Forests, 2015) and the demand for new fibres increases, bamboo's position is poised to change.

Above: Aerial image of EcoPlanet Bamboo's Nicaraguan farm shortly after planting, 2011

As an alternative fibre, bamboo has the potential to transform major timber industries, reducing pressure on remaining natural forests, 2015

© ECOPLANET BAMBOO

In light of the challenges of the twenty-first century, we need to reassess the plants we use and how we use them. As the planet moves towards 9.6 billion people by 2050 (United Nations, 2013), we need to consider new challenges in natural resource management, resilience to climate change, new notions of landscapes, plant value, and utility as well as potential resource deficits. Increasing populations and the growth of the global middle class have resulted in a rising demand for wood- and fibre-based products, contributing to a multitude of drivers of deforestation and putting pressure on the planet's remaining forests. Plantations currently provide less than 50 percent of the world's demand for roundwood, but a far lower percentage of other wood products, and both temperate and tropical forests continue to be cleared (WWF, 2015). As one of the fastest-growing plants on earth, with an estimated 1 200 (Jiang, 2007) to nearly 1 500 species worldwide (Zhou *et al*., 2005), bamboo's substitutability provides a key way of dealing with contemporary natural resource deficits. Bamboo reaches maturity within seven years and if managed correctly can be harvested every year thereafter. Moreover, it grows on marginal land, and under this production framework does not compete with food production and requires little fertilizer or water in comparison to traditional sources of fibre (EcoPlanet Bamboo, 2015b).

Global commitments to the Bonn Challenge and the New York Declaration on Forests, as well as regional commitments such as Latin America's Initiative 20 × 20, to bring a collective 350 million ha of degraded and deforested land under restoration by 2030 (Messinger and DeWitt, 2015). Investment into timberland and traditional forest plantations, both of native and exotic species, requires patient, long-term, illiquid capital. Adding degraded land into the equation further increases the timeline for productivity and financial returns. In contrast, with its fast growth rates and unique ability for continuous high yields without any requirements for replanting, bamboo has the potential to overcome these investment barriers, and attract new sources of capital, while meeting restoration goals in a tangible time frame and an economically viable manner. Commercial bamboo plantations can therefore help achieve these international restoration goals by using degraded and deforested land to restore critical ecosystem functions, while producing a sustainable source of fibre. This in turn serves as an alternative to traditional timber and as a resource to stimulate national and local economies and reduce foreign imports.

Bamboo could play an important role in the growing field of forest and landscape restoration. Forest and landscape restoration aims to recognize a matrix of landscape options across forestry and agriculture (Laestadius *et al*., 2011). It was envisioned as a framework that could be applied across a range of land uses with an emphasis on restoring ecosystem services to meet societal needs. Explicitly it is not a call to return to past visions and patterns of land use (Laestadius *et al*., 2015). To date, around 47 percent of the world's forest area has been cleared or degraded to make way for crops, cattle, cities and roads. In order to achieve large-scale restoration, artificial boundaries of forestry and agriculture need to be assessed and landscapes viewed as "mosaics" – areas that can provide different functions. Globally, 1.5 billion ha would be best suited for mosaic restoration, in which forests, trees and bamboo could be combined with other land uses, including agroforestry, smallholder agriculture and settlements. By planting bamboo as part of a larger landscape, degraded lands could be restored to productive use, thereby alleviating some of the pressure on forests from development uses, and providing communities with secure incomes, thereby reducing smaller-scale pressures that drive continued degradation (Laestadius *et al*., 2011).

BAMBOO RESTORATION BENEFITS

Rapid growth, soil binding and erosion control, adaptive capability, nutrient and water conservation of land and the provision of a continuous and permanent canopy all enable select and carefully chosen bamboo species to act as succession species for the restoration of degraded land. In a nutshell, bamboo provides key ecological benefits for soil, water and carbon sequestration as well as livelihood benefits. Firstly, soil – bamboo can grow on degraded and marginal soils, where many native species, particularly in tropical regions, have difficulty becoming established. In the case of compacted soils, bamboo's extensive interconnected root system can break up soil particles, increasing permeability, reducing compactibility and over time allowing other less competitive species to become established. Similarly bamboo has the potential to control soil erosion quickly after planting. It grows and establishes itself well on sloping terrains, hill slopes and embankments. The root system or rhizomes of bamboo form an underground network – the rhizosphere – which helps bind soil while its dense canopy reduces the impact of the elements on exposed soils. Most bamboo rhizomes are present in the top layer of soil (0–30 cm), which enables it to be effective in controlling soil erosion and stabilizing ecosystems (Mishra *et al*., 2014). According to research in China, the ability of Moso bamboo (*Phyllostachys heterocycla pubescens*) forests to stabilize soil (control of soil loss per unit area and per unit time) is 1.5 times greater than Chinese pine forest (*Pinus massoniana*) (Zheng and Hong, 1998). Moreover, bamboo can thrive in soils that are depleted of nutrients and the introduction of bamboo can enrich soil fertility. Because of its fast-growing nature and dense foliage, bamboo is able to rapidly

© ECOPLANET BAMBOO

EcoPlanet Bamboo's operations provide permanent and long-term employment for both skilled and unskilled individuals, 2015

create and maintain a thick layer of litter. This litter layer maintains a microclimate in the understorey and soil moisture – some of the most important factors for the restoration of degraded lands (Zhou *et al*., 2005).

In the case of clumping bamboos, the root system does not spread beyond the centre of the plant; it forms an intricate network that has the ability to break up compacted soils and restore permeability and aeration. It also slows the flow of water through the layers of soil. Each individual clump puts up multiple stems or culms each year. These break through the soil and create a multidimensional structure, providing habitat for a range of insects, birds and mammals. In contrast to traditional tree plantations, which generally clear-cut large areas during harvesting, individual culms from each bamboo plant within a plantation can be removed annually, an approach that stimulates growth and ensures a continuous canopy cover. Because these individual culms die naturally, their removal has little effect on forest composition, ensuring minimal disturbance to forest landscapes (EcoPlanet Bamboo, 2014a).

Secondly, water: bamboo has evergreen leaves, a dense canopy and numerous culms, which creates a strong capacity for rainfall interception and moisture retention. For example, Zheng and Hong (1998) found that the rainfall interception ratio (vegetation canopy intercepting rainfall) of Moso bamboo forest is 1.3 times greater than Chinese fir forests. The water conservation function (an index including canopy interception, water holding capacity of the litter layer and soil infiltration) in Moso bamboo forests is approximately 30 to 45 percent greater than Chinese fir forests (*Cunninghamia lanceolata*). In China, more than 90 percent of bamboo forests are found in regions of major rivers and lakes and along riverbanks, where they play an important role in regulating the flow of water through an ecosystem, protecting water sources, and reducing the effects of soil erosion caused by rainfall on bare ground (Zhou *et al*., 2005). In other areas, the restoration of degraded land into bamboo forests has been shown to regenerate water tables, securing more regular rainfall patterns and increasing the occurrence of streams, rivers and other water bodies.

Thirdly, carbon sequestration – with their rapid growth rate and high annual regrowth after harvesting, bamboo forests have high carbon storage potential (Lou *et al*., 2010). Because of bamboo's rapid growth, the annual carbon fixation of Moso bamboo forests is estimated at 1.3 times the value of that of a tropical mountain rain forest (Zhou and Jiang, 2004), and 1.4 times the value of that of Chinese fir (*Cunninghamia lanceolata*) (Zhao *et al*., 2009). In contrast to timber plantations under harvest, the long-term average of bamboo's carbon sequestration does not represent a bell curve, but rather a static line. This is due to the fact that although a portion of bamboo biomass is harvested and removed each year, this is rapidly replaced within a single growing season. The long-term average carbon sequestration and storage of a bamboo restoration project is static, regardless of the end use of the product. This high annual rate of carbon accumulation indicates that the bamboo forest is one of the most efficient types of forest vegetation for carbon fixation (Zhou *et al*., 2005).

Finally, a bamboo forest or plantation under active management represents a high need for labour. In contrast to timber plantations or managed forests, where these jobs are sporadic due to the intermediate timeframes associated with tree growth and subsequent harvesting, such jobs are permanent and long-term.

BAMBOO RESTORATION CASE STUDIES

Bamboo benefits go far beyond just restoration ecology (EcoPlanet Bamboo, 2014a). Case studies of bamboo restoration remain relatively small-scale, but some have shown promise. In India, the International Network for Bamboo and Rattan (INBAR) completed a prize-winning bamboo restoration project, which turned a degraded mining area into green, productive land (INBAR, 2003). However, the bamboo industry has generally centred on a patchwork of small farms which cannot provide the security of supply or quality of product global companies require, particularly those in the timber industry considering a fibre switch. EcoPlanet Bamboo is attempting to industrialize the bamboo industry through the development of plantations in Central America, southern Africa, West Africa and Southeast Asia using non-invasive clumping bamboo species (EcoPlanet Bamboo, 2015c). Currently EcoPlanet focuses on replacing wood and fibre sourced from old growth forests across industries including textiles (rayon and viscose), pulp and paper (targeting toilet and tissue paper) and bioenergy, but eventually aims to extend this substitutability within the textile industry to cotton. Cotton causes severe and widespread deforestation and requires significantly more water and chemicals per ha to grow than bamboo. If grown correctly, bamboo is a far more sustainable solution (EcoPlanet Bamboo, 2015b).

In contrast to donor aid or payments for ecosystem services (PES), EcoPlanet's operations provide a private-sector example of an economically viable means by which to achieve landscape restoration at the landscape scale. EcoPlanet is working to restore an initial 40 000 ha globally while also providing a certified and secure source of fibre for products and markets that still contribute to global deforestation. While PES can provide initial financing, bamboo projects become self-sustaining after bamboo reaches maturity, typically within five to seven years. As governments around the world work to meet conservation commitments and companies seek to identify sustainable sources of timber, bamboo should be considered as a resource that can simultaneously achieve these goals (EcoPlanet Bamboo, 2014b).

In Nicaragua, EcoPlanet began operating in 2011. Located within the semi-autonomous Southern Atlantic State of Nicaragua's Caribbean coast, the area underwent severe deforestation during the 1970s and 1980s.

Selective manual harvesting of individual culms ensures that restoration and ecosystem benefits are permanent, 2015

© ECOPLANET BAMBOO

Once exposed to heavy rainfall, the shallow topsoil was quickly eroded, and productivity of the soils rapidly decreased. Agriculture was stopped, and low-intensity cattle farming followed, resulting in high soil compaction. The project uses *Guadua aculeata*, a native species of giant clumping bamboo that occurs naturally within the forest, to restore 5 000 ha of highly degraded land into commercial plantations, providing more than 250 permanent jobs and conserving more than 600 ha of remnant patches of tropical forest, resulting in habitat connectivity and increasing the ability of the landscape to provide core ecosystem functions. Native *Guadua aculeata* is one of the few plants that is able to withstand these conditions and is better able to tolerate the region's extreme rainfall and compacted soil than native tree species (EcoPlanet Bamboo, 2014a).

In southern Africa, EcoPlanet's farm is located in the agricultural belt of South Africa's Eastern Cape. Farms in this area were under intensive chemical agriculture for the production of pineapples for over a century, resulting in soils that are highly depleted. With the decline of South Africa's pineapple industry, many of the farms in this area went out of production. This plantation is focused on naturalized *Bambusa balcooa* grown from tissue culture plantlets. The South African case is the first example in the world of large-scale restoration using tissue culture plantlets to overcome a lack of bamboo planting material. The lack of restoration projects using tissue culture plantlets has been a major barrier to the industrialization of bamboo outside China. The project has restored 485 ha of highly degraded land, preserved more than 140 ha of wildlife corridors and native vegetation, and created approximately 100 jobs in an area that has suffered severe unemployment since the crash of South Africa's pineapple industry. The project further stimulates local economies by providing an alternative fibre for the manufacturing of activated carbon for domestic markets.

In West Africa, EcoPlanet has undertaken a public private partnership with the Ghana Forestry Commission aimed at restoring 15 000 ha of highly degraded land located within the country's system of forest reserves. Contrary to the name, these areas are not protected natural forest, but areas highlighted as being of critical importance for maintaining the country's ecosystems benefits and protection of microclimates for the cocoa industry. Lack of available funds combined with high pressure from illegal charcoal production have turned these reserves into highly degraded areas with remnant forest patches. EcoPlanet's initial project involves restoring 3 500 ha in the Ashanti Region, and protecting the remaining forest from further deforestation through the provision of secure and attractive employment to surrounding communities which suffer extreme poverty. Restoration of a further 11 500 ha in Ghana's Northern Region, an area that has been heavily marginalized and has suffered severe land clearance, is set to begin in 2016. These projects are aimed at the production of toilet paper for European and US markets, replacing old growth boreal fibre. Many major brands have already made public commitments to move to such an alternative fibre, in an attempt to reduce their deforestation footprints.

In Asia, the deforestation footprint is significant. With countries such as the Philippines and Indonesia being composed of thousands of small islands and characterized by rapidly growing economies, the need to stabilize land clearance while providing a fibre to feed pulp mills, as well as an increasing need for energy security, has become a priority for governments. In the context of the energy security of an island nation it must be distributed, local and available on demand. Bioenergy meets all these requirements and bamboo can be a sustainable feedstock requiring minimum land area to feed bioenergy facilities. EcoPlanet's Southeast Asia expansion is targeting the restoration of highly degraded landscapes to provide a dedicated source of bamboo biomass for the combined production of renewable energy and a cleaner pulp for the textile industry (EcoPlanet Bamboo, 2014a, 2014b, 2015b). General Electric's biogasification technology has been developed for distributed power, enabling smaller islands such as those in the Philippines or Indonesia to combine smaller-scale bamboo restoration projects with onsite power generation (General Electric, 2014).

CHALLENGES AND OPPORTUNITIES

International support is growing for bamboo to be seen as an important plant for landscape restoration. INBAR has tasked 40 nations to restore 5 million ha of degraded lands and areas of low-quality bamboo production into productive, healthy bamboo forests. For example, the Chinese State Forest Administration has pledged to plant 1 million ha and restore 3 million ha, the Philippines will reforest at least 500 000 ha, and India will have 100 000 ha of degraded land under bamboo restoration programmes by 2020. The Ethiopian Government plans to restore nearly 500 000 ha of degraded land (Buckingham, 2014b).

While it may be seen as a weed or perceived mostly as an invasive species (although there are native bamboo species on almost every continent and only a small portion of the entire genera show characteristics of invasiveness), the perception of bamboo needs to be updated, brought into mainstream forestry institutions, integrated into national definitions of forests and brought into national greenhouse gas inventories (Buckingham, 2014b). For example, in South Africa, as elsewhere, bamboo is not part of the natural forest matrix in the country and is not recognized as a forest species. This poses a number of policy challenges. It is unclear whether bamboo plantations should come under the jurisdiction of the Ministry of Forestry, the Ministry of Agriculture or some other entity. The ecology and growth patterns of bamboo are those of a grass, and yet a grove of giant bamboos, more than 30 metres tall and with diameters not dissimilar to trees, has some of the characteristics of a forest. Furthermore, bamboo provides a fibre that is similar to wood (EcoPlanet Bamboo, 2014c). In order to truly integrate bamboo, global policy and markets need to change.

Crisis in natural resource management has historically led to innovation. The timber crisis in sixteenth- and seventeenth-century Europe, when timber was the key energy resource, led to the development of coal as a fuel, which in turn made the technologies of the Industrial Revolution. It is argued that the Industrial Revolution occurred in the United Kingdom 50 to 100 years earlier than any other country because of the innovative response to scarcity of resources (Hobhouse, 2004). Bamboo therefore can fit into a new resource paradigm, in an age

Two-year-old native bamboo reconnecting remnant forest patches while securing an economic future for the landscape, 2013

© ECOPLANET BAMBOO

that needs innovative responses to scarcity of resources (Buckingham, Wu and Lou, 2013). Planting bamboo is particularly important in locations where a return to pure or mixed forested areas is not realistic. In a landscape mosaic approach, bamboo is planted in areas that combine forests and trees with other land uses. That is not to suggest that bamboo should be utilized to restore all landscapes. Of course, bamboo cannot be a panacea; there are many management, propagation and technology challenges to overcome, as well as concerns that to provide such restoration benefits it is only grown and harvested under a framework of sustainability.

EcoPlanet's experiences demonstrate how bamboo is able to address both natural resource management challenges and the need to facilitate restoration of degraded lands. The case studies are examples of restoration at the landscape level that meet economic, environmental and social objectives. They demonstrate to individuals and investment institutions that securing attractive long-term returns while restoring, rather than extracting, natural resources is not only possible but preferable. Restoration efforts often focus on planting native species, but fail to provide the funds necessary for the long-term efforts required for ecosystems to become self-regenerating. Tree plantations also require long-term capital. EcoPlanet's model has successfully overcome these capital requirements, reducing the time for return on investment and proving competitive returns. The projects have also secured political risk insurance, which has been significant in overcoming many investment barriers in regions that have a high perceived risk from a capital perspective. Access to such insurance encourages further investment from institutional sources, allowing projects to be scaled up and restoration efforts maximized.

Without addressing the underlying drivers of deforestation and land-use change, it is unlikely that restoration efforts will succeed. For major industries to shift to bamboo as an alternative fibre, the supply must be secure. Like any other crop, bamboo requires considerable inputs and management to be produced commercially. The level of these inputs affects productivity and the quality of the fibre. A smallholder model is unlikely to be able to provide enough high-quality resources for a large-scale industry, and lower levels of processing (such as handicrafts) cannot sustain the costs associated with production. Scaling up restoration efforts to the level necessary to achieve a significant global impact requires a shift in approach from non-governmental organizations to the private sector (EcoPlanet Bamboo, 2014a). Private-sector engagement with alternative resources will open the door for more sustainable approaches to natural resource management. History has shown us that the value of natural resources changes over time. It is time to reassess bamboo's famous "weedy" reputation and evaluate how it can be used for climate change resilience and restoration. Today's weeds can become tomorrow's valuable resources. ◆

© ECOPLANET BAMBOO

Bamboo integrated into the landscape prior to complete canopy closure, 2014

References

Buckingham, K. 2014a. *Bamboo: The secret weapon in forest and landscape restoration?* World Resources Institute blog (available at http://www.wri.org/blog/2014/02/bamboo-secret-weapon-forest-and-landscape-restoration).

Buckingham, K. 2014b. *Rebranding bamboo for Bonn – The 5 million hectare bamboo restoration pledge*. World Resources Institute blog (available at http://www.wri.org/blog/2014/12/rebranding-bamboo-bonn-5-million-hectare-restoration-pledge).

Buckingham, K., Jepson, P., Wu, L., Rao, I.V.R., Jiang, S., Liese, W., Lou, Y. & Fu, M. 2011. The potential of bamboo is constrained by outmoded policy frames. *AMBIO*, 40(5): 544–548.

Buckingham, K., Wu, L. & Lou, Y. 2013. Can't see the (bamboo) forest for the trees: Examining bamboo's fit within international forestry institutions. *AMBIO*, 43(6): 770-778.

Crosby, A.W. 2004. *Ecological imperialism: The biological expansion of Europe, 900–1900*. Studies in Environment and History. 2nd ed. Cambridge, Cambridge University Press.

EcoPlanet Bamboo. 2014a. 4.6 Commercial bamboo plantations as a tool for restoring landscapes. *ETFRN news 56: Towards productive landscapes*. November 2014.

EcoPlanet Bamboo. 2014b. *Bamboo: A mechanism to reconnect forest fragments and restore ecosystems; landscapes for people, food and nature* (available at http://peoplefoodandnature.org/blog/bamboo-a-mechanism-to-reconnect-forest-fragments-and-restore-ecosystems).

EcoPlanet Bamboo. 2014c. *Land restoration with bamboo, Eastern Cape, South Africa*. 20 June 2014. EcoPlanet Bamboo South Africa.

EcoPlanet Bamboo. 2015a. EcoPlanet Bamboo. Website (available at http://www.ecoplanetbamboo.com/about-us).

EcoPlanet Bamboo. 2015b. *Business green features EcoPlanet Bamboo*. 12 January 2015 (available at http://www.ecoplanetbamboo.com/news/business-green-features-ecoplanet-bamboo).

EcoPlanet Bamboo. 2015c. *Restoring land and reducing deforestation* (available at http://www.ecoplanetbamboo.com/global-plantations).

General Electric. 2014. *GE supports need for distributed power in Indonesia with announcement of key projects*. Press release (available at http://www.genewsroom.com/Press-Releases/GE-Supports-Need-for-Distributed-Power-in-Indonesia-with-Announcement-of-Key-Projects-273673).

Hobhouse, H. 2004. *Seeds of wealth: Four plants that made men rich*. London, Pan Publishing.

INBAR. 2003. *Greening red earth*. Beijing, INBAR.

Jiang, Z.H. 2007. *Bamboo and rattan in the world*. Beijing, China Forest Publishing House.

Laestadius, L., Maginnis, S., Minnemayer, S., Patapov, P., Saint-Laurent, C. & Sizer, N. 2011. Mapping opportunities for forest landscape restoration. *Unasylva*, 238 (62).

Laestadius, L., Reytar, K., Maginnis, S. & Saint-Laurent, C. 2015. *Demystifying the world's forest landscape restoration opportunities*. World Resources Institute blog (available at http://www.wri.org/blog/2015/03/demystifying-worlds-forest-landscape-restoration-opportunities).

Lou, Y.P., Li, Y.X., Buckingham, K.C., Henley, G. & Zhou, G.M. 2010. *Bamboo and climate change mitigation*. Beijing, INBAR.

Messinger, J. & DeWitt, S. 2015. *Bonn Challenge on track to meet land restoration goal by 2020*. World Resources Institute blog (available at http://www.wri.org/blog/2015/03/bonn-challenge-track-meet-land-restoration-goal-2020-0).

Mishra, G., Giri, K., Panday, S., Kumar, R. & Bisht, N.S. 2014. Bamboo: Potential resource for eco-restoration of degraded lands. *Journal of Biology and Earth Sciences*, 4(2): 130–136.

New Forests. 2015. *Timberland investment outlook 2015–2019* (available at https://www.newforests.com.au/wp-content/uploads/2015/07/New-Forests-Timberland-Investment-Outlook-2015-2019.pdf).

Scott, J.C. 1998. *Seeing like a state*. New Haven, Yale University Press.

Song, X., Zhou, G., Jiang, H., Yu, S., Fu, J., Li, W., Wang, W., Ma, Z. & Peng, C. 2011. Carbon sequestration by Chinese bamboo forests and their ecological benefits: Assessment of potential, problems, and future challenges. *Environmental Reviews*, 19: 418–428.

United Nations. 2013. *World population projected to reach 9.6 billion by 2050*. United Nations (available at https://www.un.org/en/development/desa/news/population/un-report-world-population-projected-to-reach-9-6-billion-by-2050.html).

WWF. 2015. Saving forests at risk. *In: Living Forests Report*, Chapter 5. WWF (available at http://d2ouvy59p0dg6k.cloudfront.net/downloads/living_forests_report_chapter_5_1.pdf).

Zhao, M., Xiang, W., Peng, C. & Tian, D. 2009. Simulating age-related changes in carbon storage and allocation in a Chinese fir plantation growing in southern China using the 3-PG model. *Forest Ecology and Management*, 257(6): 1520–1531.

Zheng, Y. S. & Hong, W. 1998. Management of *Phyllostachys pubescens* stand. Xiamen, Xiamen University Publishing House.

Zhou, B., Fu, M., Xie, J., Yang, X. & Li, Z. 2005. Ecological functions of bamboo forest: Research and application. *Journal of Forestry Research*, 16(2): 143–147.

Zhou, G.M. & Jiang, P.K. 2004. Density, storage and spatial distribution of carbon in *Phyllostachys pubescens* forest. *Scientia Silvae Sinicae*, 6: 20–24. ◆

© WEFOREST

Funding forest landscape restoration using a business-centred approach: an NGO's perspective

V. Gutierrez and M.-N. Keijzer

The private sector constitutes a promising source of funding for the restoration of degraded forest landscapes.

Victoria Gutierrez is the Director of Reforestation Projects at WeForest.
Marie-Noelle Keijzer is the Chief Executive Officer and Co-founder of WeForest.

There is a growing realization that the private sector constitutes a promising funding mechanism for a wide community of players working to restore degraded forest landscapes. For non-governmental organizations (NGOs), an understanding of businesses' needs, the motivations of private enterprises and appropriate engagement strategies all require careful consideration, particularly as traditional funding options are unlikely to suffice in an evolving environmental finance market.

The aim of this article is to examine financial solutions for forest landscape restoration (FLR) projects through WeForest's understanding and experience of corporate engagement.[1] It will look beyond traditional funding mechanisms to discuss the need for business-centred approaches that engage with the corporate community, including end users. By illustrating how WeForest (WF) has procured corporate funding through marketing services and "tree planting"[2] products, it will argue that

Above: Umiam watershed in the East Khasi Hills, northeast India project

[1] Although the private sector comprises a broad range of organizations of various sizes and ownership structures, the article will focus on companies and corporates, since these represent the core of WeForest's activity and have the greatest capital potential for funding FLR in the near future.

[2] The term "planting" is used in a broad sense to refer to any practice that grows trees, from physically placing seedlings on the ground to seed sowing and assisted natural regeneration.

Smallholder farmer in the United Republic of Tanzania

Box 1
WeForest

WeForest (WF) is a non-profit organization that, since 2010, has mobilized nearly 140 private companies from 24 countries to invest in a portfolio of reforestation and restoration projects designed to increase tree cover along with social, economic, and other ecological benefits.

Contrary to environmental NGOs that generate monies from subscription fees or statutory funding, WF is financed by the private sector, and to a limited extent, by private individuals. Over half of WF's sponsors (53 percent) fall within five industry sectors (i.e. service providers and consulting, information technology and telecommunications, fashion and beauty, manufacturing and environmental industries). The manufacturing sector, followed by food and fast-moving consumer goods, constitute the top three financial contributors.

WeForest uses the concept of impact marketing to involve and enable companies to connect with their end consumers through wider outreach campaigns that have tangible benefits for their business and clear benefits for the environment.

corporate engagement strategies that are associated with a positive impact for the environment constitute a strong alternative to traditional philanthropic funding.

The past 20 years have seen a shift in the way that the private business community is perceived. Corporates, often viewed as agents of environmental damage and ecological crisis, are being called upon as essential partners in ecosystem conservation and restoration. Detractors describe the involvement of private enterprises as controversial, since businesses prioritize profit maximization over the preservation of the public good (Newell, 2000). Discrepancies between what companies report and what they do on environmental issues continue to attract criticism (see, for example, Bowen and Aragon-Correa, 2014). Nevertheless, it is now widely accepted that the business and industry sectors need to be part of the solution to global environmental problems (Kissinger, Morogo and Noponen, 2015).

In recent years, the urgent need to respond to climate change, deforestation and land degradation challenges has intensified interest in exploring partnership opportunities that benefit both the environment and the private sector. More than ever, businesses are looking to invest in large-scale conservation programmes, agroforestry systems, and green commodity markets that secure the ecosystem products and services on which their sustainability depends. For example, the investment in, or payment for, watershed services is an emerging sector that has received attention from the beverage industry (Stanton *et al*., 2010). About US$6.5 billion (62 percent of the annual global funding for conservation) is provided by green commodities as investment in


© IPE

Tree seedlings at a nursery in Brazil

sustainable and certified products, whilst US$3 billion (29 percent) is allocated to carbon offsets (Parker *et al*., 2012). The scale of these markets is significant because it allows the trade of ecosystem products and services on a global scale.

STATE OF PRIVATE BUSINESS INVESTMENT

Very few studies have explicitly quantified private-sector investment practices and interests in FLR (Dewees *et al*., 2011), and, when explored, the analysis has generally focused on commodity markets or on payments for ecosystem services. For example, the first report examining the market for conservation-related impact investments indicated rapid growth and interest in areas that focus on habitat and natural resource protection (EKO and NatureVest, 2014). The 56 investors surveyed quadrupled their investments between the periods 2004–2008 and 2009–2013 (from US$23 million to US$100 million) and expected the capital deployed in general conservation to nearly triple in 2014–2018 (i.e. US$5.6 billion). Unfortunately, the corporate sector was under-represented in the report and FLR was not explicitly accounted for. Despite the shortage of data, it remains the case that a strong demand from private investors can offer financing for scalable and effective programmes that can generate returns (CS, WWF and McKinsey & Company, 2014). In this respect, advances in technological capacity to monitor forests are likely to facilitate performance-based investment for forests.

There are multiple reasons to involve businesses in landscape restoration initiatives. Firstly, endorsing good practices within the industry sector can have a major impact on forest protection and on the sustainability and traceability of commodity markets, as well as influencing sustainable consumer behaviour. Secondly, individual companies and industry associations may have a significant influence on governments. And thirdly, these players are well placed to take action and have the resources to facilitate the implementation of environmental policies, engage in sustainable entrepreneurial initiatives and evaluate impact. The private sector can play an important role in the implementation of environmental frameworks, for example in relation to representing and implementing the Convention on Biological Diversity (Bled, 2009).

BEYOND PHILANTHROPY

Despite claims that philanthropy is thriving, funds sourced via this mechanism are insufficient to deliver the finance required to meet the climate mitigation goals or conservation funding targets. For example, according to The Foundation Center, donations earmarked for climate change efforts are on a continuous growth curve. The Forbes' BNP Paribas Individual Philanthropy Index for 2013 reports that environmental causes were the focus of 46 percent of core programmes funded by more than 300 high-net-worth individuals worldwide. Also, the 2014 *Coutts Million Dollar Donors Report* indicated that the total value of donations of US$1 million or higher has steadily increased in all areas during the past eight years, reaching a total of US$26.3 billion in 2013. Yet, from this budget, only US$170 million (less than 1 percent) was allocated to environmental causes.

Moreover, philanthropy has a range of priorities in addition to climate change and the environment, some of which may be in direct competition. It is subject to changing influences and is therefore a non-sustainable strategy for solutions that require implementation over a long period (philanthropic donations, for example, witnessed the highest level of donor fatigue among WF's funding sources). Philanthropy may be relevant in some instances, such as for project seed funding or capacity building. Charity giving can notably play a key role in financing initial costs associated with carbon certification. However, organizations seeking to attract sustainable finance will need to look beyond private or corporate philanthropy.

CORPORATE ENGAGEMENT OPTIONS, FROM CORPORATE SOCIAL RESPONSIBILITY TO IMPACT MARKETING

Firms that engage in environmental action are motivated to do so for a number of reasons: compliance with voluntary production standards to attain greater supply-chain efficiency; diversification and market expansion; leadership and market positioning; improvement of public image and boosting of staff motivation; improvement of external relations and avoidance of bad reputation risks that could negatively impact the firm's activities (Allet, 2014). Accordingly, companies can take distinct approaches. One such is the corporate social responsibility (CSR) path, which comprises philanthropic donations and offsets, and is mainly viewed as a branding strategy. Alternatively, the investment route is driven by financial return on investment (ROI), risk assessment and, more recently, the need to demonstrate impact. Interviews with senior corporate executives suggest that the biggest frustration for investors was the shortage of solid business cases for investment opportunities and the burden of documenting impact (EKO and NatureVest, 2014). As trends in global market demand for environmental action will continue into the future, it becomes urgent to create opportunities for businesses to finance responsible FLR.

Traditionally, purchasing carbon credits within the voluntary carbon market has been the main option for a company to offset its footprint in compliance with CSR. The advantage of carbon offsetting is its ubiquity across industries, which makes it a straightforward and broadly applicable action. While an increasing number of companies seek to understand and report on their environmental footprint, most firms will focus on carbon emissions, with fewer being concerned about water or forest footprints (WWF, 2014). Exceptions are found within the fashion industry, where companies are beginning to report on the footprint associated with water-intensive cotton production; some other companies have begun to report on their supply-chain forest footprint (Hulse *et al*., 2013; WWF, 2014). European buyers generated the largest demand for forestry emission reductions in 2013, and constituted the largest source of demand for projects based in Latin America, Asia, and Africa (Goldstein and Gonzalez, 2014).

Non-extractive forest initiatives are of interest to financiers who prioritize climate change mitigation solutions. Carbon credits, when associated with livelihood projects, provide a variety of climate change adaptation and mitigation benefits. For example, in 2013, carbon offset initiatives were reported to have created 9 000 jobs, trained or built the capacity of 150 000 people and protected 13 million ha of habitat for endangered species, as well as offering US$41 million in livelihood benefits such as education, healthcare and infrastructure (Goldstein and Gonzalez, 2014). These co-benefits, however, were not a decisive factor for the companies that were willing to fund carbon-certified projects.

WeForest has not engaged in the voluntary carbon credit market. Several of its projects are carbon certified or in the process of completing validation under the Plan Vivo standard, which is particularly suitable for smallholder- and community-based projects since it emphasizes social and biodiversity dimensions. At the project level, the standard adds value to the diversification of income streams and long-term incentives that can motivate local populations to safeguard their assets.

Like carbon offsetting, *insetting* is a strategy that enables firms to generate positive climate and social impacts by supporting schemes that benefit the company's stakeholders. Companies may fund projects within their supply chain and offset their carbon footprint within the business ecosystem of suppliers, partners and local communities. For businesses, insetting brings social co-benefits that work to strengthen the long-term business strategy, and helps businesses understand and potentially improve their supply chain, which in turn can generate competitive advantage. For example, in 2014 Nespresso declared its intention to inset its operational carbon footprint through an agroforestry scheme designed to increase resilience to climate change. Insetting initiatives may be developed as investments by firms in partnership with external stakeholders, but the significant effort that is required to develop and manage the scheme may make this strategy unattractive to some companies.

Despite a short history, WeForest has adapted to new ways of working with firms. Once solely funded through private philanthropy, the organization has broadened its fundraising strategy to develop products and services designed to serve the interests of companies, initially catering to the needs of firms looking to offset their business footprint and subsequently offering custom-made marketing tools that embed trees into the core business of consumer-facing companies. Trees are used as a currency to engage stakeholders and to have an impact on local ecosystems through reforestation projects that focus on local communities.

WF's approach to fundraising moves across the divide between traditional CSR and *impact marketing* (cause marketing). While companies who invest in CSR activities typically do so by associating a brand name with the benefits derived from initiatives such as carbon offsetting, impact marketing involves packaging a product or service with a specific FLR project and consequent impact (e.g. planting trees with the purchase of product items). It is positioned halfway between philanthropy and investment. For the company, the product or services offered can be made visible through association with tree-planting activities, the multiple benefits of forests, and the need for a sustainable future. Trees planted can be shared on social media, boosting visibility and brand awareness, shifting from traditional marketing towards crowd marketing.

For WeForest, these business approaches have led to similar average revenue and have had no significant impact on donor loyalty. However, the advantage of this approach over a CSR strategy is threefold. Firstly, there are far larger budgets available for marketing. According to eMarketer 2014, advertisers worldwide were expected to spend US$545.40 billion on paid media in 2014 (US$667.65 billion by 2018). In contrast, in 2014 the World Bank valued global carbon trading schemes at US$30 billion; carbon offsets from forestry and land-use interventions combined (core to CSR) generated less than US$200 million in 2013. Thus marketing strategies have the potential to mobilize financing on a scale needed to fund FLR. Secondly, advertising budgets take priority over CSR in times of spending cuts, and are therefore more protected by companies from budget fluctuations. Thirdly, strategies differ in the visibility created around project activities, which contributes to environmental and socioeconomic awareness. For impact marketing, there is an amplifying outreach factor since with every item or service sold, there is an environmental message that can speak to the end consumer. The environmental message that relates to trees and the co-benefits of forests for communities, biodiversity, etc. can be more widely disseminated to the public. The added value of message amplification may serve to raise awareness and possibly stimulate appropriate consumer behaviour. Compared to CSR, impact marketing is a wider outreach strategy. Impact is sought at the level of the project and at the level of end-user engagement.

The majority of companies (52.8 percent) who have financed WeForest's project portfolio did so to develop their CSR, while 45.6 percent of firms spent funds from their marketing budget, and just over 1 percent of contributions were classified as philanthropic donations. This is in line with a general trend in which CSR is the most common "buyer" motivation. In 2013, the majority of carbon credits (a total of 29 $MtCO_2e$) were purchased by firms seeking to meet CSR objectives or demonstrate industry leadership (Goldstein and Gonzalez, 2014).

WeForest has observed a growing interest from companies in linking positive actions and story-telling with their products and services. "Business-to-consumer" and "business-to-business" companies can promote their products while supporting reforestation projects by using "doing good" messages. "Trees", rather than land cover, are used as currency since the concept and benefits of trees are easily understood by most stakeholders.

Box 2
Case study: Eneco's impact marketing campaign

In 2014, WF provided Eneco (Belgium), a green energy supplier, with a consumer engagement tool that enabled the company to offer its customers the choice of a discount of 20€ on their next bill or the planting of 40 trees in one of two of WF's projects. Results showed that 20 percent of customers chose to plant trees using WF's TreeApp. Two-thirds of customers visited the company's website and 50 percent went on to read more about the company's sustainability strategy, spending an average of 50 seconds online. The app can be tailored to appeal to a wide range of businesses, fitting almost any requirements, including customized gamification. Recipients can follow the progress of the project and share their tree-planting contribution via social networks.

For example, a *buy2-get-1tree* campaign allowed Délifrance to plant over 2 million trees; the search engine Ecosia is planting a tree every several mouseclicks and allocating 80 percent of its revenue to FLR, expecting to restore 3 000 hectares in 2015 (3 million trees). For companies, the mobile TreeApp can be used as a new type of loyalty programme around tree planting that reinforces a positive message far beyond that associated with offsetting schemes. These initiatives provide businesses with a low-risk, positive message that can be easily understood by stakeholders and end consumers.

BARRIERS TO ENGAGEMENT

Public trust in corporate CSR performance, following a series of revelations concerning corporate scandals, has followed a negative trend. CSR strategies continue to be construed as a tactic used by companies to greenwash or to evade binding regulations, since footprint disclosure relies on businesses' goodwill in applying voluntary regulations (Clapp, 2005). Exceptions to the rule are found in France, where businesses with more than 250 employees are required by law, as of December 2011, to measure and report on greenhouse gas (GHG) emissions. The negative images surrounding corporates, however, and the fact that carbon neutrality does not preclude companies from producing negative social or environmental impacts, has led to some resistance from companies to engage in carbon-offsetting initiatives, since they will remain under scrutiny regardless. These companies may be more inclined to improve public image through marketing.

WHAT NEXT?

Pioneering companies are thinking beyond being transparent about their environmental footprint, realizing that revenue should be attached to positive impact. Firms are aware of the need to enhance credibility through tangible impacts, to innovate and improve sustainable practices, and to engage with stakeholders, especially consumers. Yet innovative leaders need to take this further so as not only to pursue positive social and ecological impacts through FLR initiatives, but to take responsibility for the outcomes.

Social impact bonds – investments targeting positive social impacts as well as a financial return – are a new investment mechanism that has the potential to benefit society, the ecosystem and investors (Center for Global Development and Social Finance, 2013). Previously applied to social

© WEFOREST

Acacia raddiana ***seedling emerging after rains in Burkina Faso***

and health outcomes, there may be opportunities to explore their application in the context of FLR. For example, thanks to increased crop yields, the implementation of agroforestry projects can reduce land encroachment into protected forest land and thereby lead to financial returns for investors in the form of decreased social expenditure. The initial investment plus interest will be repaid by a donor organization if, and only if, the desired impact is achieved.

Mobilizing investors, however, will require wider sets of skills from NGOs. For example, outcome-based financing mechanisms require specialized capacity and skills for development, which is likely to exclude most small to medium environmental NGOs from accessing this finance. Expertise on financial feasibility and business case proposals requires a good working knowledge of the ROI methodology. Allocation of funds for additional capacity building within NGOs is often construed negatively by NGO watchdogs that focus on financial performance. Hence, NGOs that are concerned about their reputation are under pressure to maintain low overheads, which keeps capacity-building potential to a minimum, and thereby limits diversification of funding streams and scalable impact.

CONCLUSIONS

Now, more than ever, private industry is seen as an important stakeholder in identifying solutions for the reforestation and restoration of forest landscapes. By recognizing the multifunctionality of landscapes, the FLR approach is well-suited to bringing together, from across industry sectors, investors seeking attractive and diverse returns while safeguarding the ecosystem and people's livelihoods. NGOs have an important role to play in accessing innovative financing sources to address the gap in national and international forest restoration financing, and to translate these into sensible action. This will require continuous adaptation to an evolving finance market. ◆

Box 3

© WEFOREST

Khasi women form self-help groups that support individual economic development through interloaning and livelihood schemes

India, building capacity to facilitate investment

Since 2014, WeForest has partnered with the KSKHAWUMW society, a federation formed by 10 Himas (governing units) in the East Khasi Hills to restore degraded forest landscape through assisted natural regeneration and enrichment planting. So far, the project has funded the reforestation of 1 500 ha, built capacity for community-based ecotourism enterprise, and enabled microfinance and livelihood schemes, including home-based nurseries run by women. These livelihood initiatives integrate sustainable natural resource management, and are integral elements of small-scale enterprises. This approach prepares the stage for investors seeking business opportunities that have organizational and entrepreneurial capacity. In the case of India, business potential could be linked to non-timber forest products such as medicinal wintergreen oil.

Zambia, promoting market opportunities to integrate smallholders in the bioenergy supply chain through ecological restoration and livelihood development

In partnership with the local private sector, the project aims to create output market linkages for the supply of sustainable biomass that is expected to result from the ecological restoration of 400 underused and degraded miombo woodlots managed by smallholder farmers for natural regeneration and biomass harvest. The biomass is sold by farmers to a local mill for processing into woodchips, designed to fuel the *Peko Pe* cooking stove sold by a local company. Woodchips are sold alongside cooking stoves as a clean alternative to the unregulated charcoal market that continues to drive deforestation in Zambia. WeForest is subsidizing up to 3 000 stoves to stimulate sales in the region and, at the same time, create a demand for woodchips. Through a performance-based approach, the scheme manages behavioural change on the part of farmers through training, peer-to-peer knowledge transfer, and participatory data collection through SMS mobile technology. The project is part of a larger programme of livelihood initiatives (i.e. honey production, women's home-based nurseries of high-value fruit trees, and the planting of trees for timber) that are key in promoting the resilience of both farmers and the local businesses. By developing and linking both suppliers and markets, the project enables the development of the value chain in terms of forest and non-forest timber products while gaining net forest cover.

References

Allet, M. 2014. Why do microfinance institutions go green? An exploratory study. *Journal of Business Ethics*, 122(3): 405–424.

Bled, A. 2009. Business to the rescue: private sector actors and global environmental regimes' legitimacy. *International Environmental Agreements: Politics, Law & Economics*, 9(2): 153–171.

Bowen, F. & Aragon-Correa, J.A. 2014. Greenwashing in corporate environmentalism research and practice. The importance of what we say and do. *Organization & Environment*, 27(2): 107–112.

Center for Global Development & Social Finance. 2013. *Investing in social outcomes: development impact bonds. Report of the Development Impact Bond Working Group* (available at http://international.cgdev.org/sites/default/files/investing-in-social-outcomes-development-impact-bonds.pdf).

Clapp, J. 2005. Global environmental governance for corporate responsibility and accountability. *Global Environmental Politics*, 5(3): 23–34.

Coutts Million Dollar Donors Report. 2014 (available at http://philanthropy.coutts.com/en/reports/2014/executive-summary.html).

CS, WWF & McKinsey & Company. 2014. *Conservation finance: moving beyond donor funding toward an investor-driven approach* (available at https://www.credit-suisse.com/ch/en/about-us/corporate-responsibility/banking/conservation-finance.html).

Dewees, P., Place, F., Scherr, S.J. & Buss, C. 2011. *Investing in trees and landscape restoration in Africa: what, where, and how*. Washington, DC, Profor.

EKO & NatureVest. 2014. *Investing in conservation: a landscape assessment of an emerging market* (available at http://www.naturevesttnc.org/pdf/InvestingInConservation_Report.pdf).

Goldstein, A. & Gonzalez, G. 2014. *Turning over a new leaf: State of the Forest Carbon Markets 2014*. Forest Trends (available at http://www.forest-trends.org/documents/files/doc_4770.pdf).

Hulse, J., Crosbie, L., McCoy, K., Walker, N. & Davis, F. 2013. *The forest footprint disclosure annual review 2012*. Oxford, UK, Global Canopy Programme.

Kissinger, G., Morogo, M. & Noponen, M. 2015. Private sector investment in landscape approaches: the role of production standards and certification. *In* Minang, P.A., van Noordwijk, M., Freeman, O.E., Mbow, C., de Leeuw, J. & Catacutan, D. *Climate-smart landscapes: multifunctionality in practice*. Nairobi, Kenya, World Agroforestry Centre.

Newell, P. 2000. *Climate for change: non-state actors and the global politics of the greenhouse*. Cambridge, Cambridge University Press.

Parker, C., Cranford, M., Oakes, N. & Leggett, M., eds. 2012. *The little biodiversity finance book*. Oxford, UK, Global Canopy Programme.

Stanton, T., Echavarria, M., Hamilton, K. & Ott, C. 2010. *State of watershed payments: an emerging marketplace*. Ecosystem Marketplace (available at: http://www.ecosystemmarketplace.com/pages/dynamic/resources.library.page.php?page_id=7599&section=home).

WWF. 2014. *Living Planet Report 2014. Species and spaces, people and places.* McLellan, R., Iyengar, L., Jeffries, B. & Oerlemans, N., eds. Gland, Switzerland, WWF. ◆

© FAO

Landscape in Morocco

The Forest Communicators Network in the Mediterranean and Near East reinforced its pledge to increase the visibility of forest issues in the region

Communications experts from Algeria, France, Greece, Lebanon, Morocco, Spain, Tunisia and Turkey met on 9–11 November 2015 in Rabat, Morocco. The network agreed on a series of commitments that include stepping up communication on the need to boost the resilience of the region's forests to increasing threats – largely from climate change, fire, storms, pests and diseases.

The network pledged to define a common vision and clear messaging for the region's forests to improve cooperation on communication issues, and to advocate for communication to be incorporated into policy decisions and planning from the outset. Facilitated by FAO with support from GIZ and the governments of Austria and Finland, the workshop also provided participants with capacity-building to refresh social media skills.

More information about the regional Forest Communicators Networks can be found here: *http://www.fao.org/forestry/communication-toolkit/en*

FAO European Forestry Commission highlighted sustainable management of Europe's forests

Hosted by Switzerland in the town of Engelberg, the joint session of the FAO European Forestry Commission and the UNECE Committee on Forests and the Forest Industry (Silva2015) took place on 2–6 November, concurrently with European Forest Week 2015.

Sustainable management of forests, which cover 33 percent of Europe's land area, was a major focus of the meeting.

Government representatives, forest owners, businesses, environmental NGOs, academics and students attended the event, which also focused on the role of sustainable forest industries in the region's economy.

The session reviewed recent global and regional policy developments and their impact on Europe's forestry agenda, including the recently adopted Sustainable Development Goals and the outcomes of the XIV World Forestry Congress, held in South Africa in September.

Other topics of discussion included the region's action plans for biodiversity conservation and climate change mitigation and adaptation, as well as the need for countries to recognize the "invisible" contribution of forests to human safety and wellbeing, such as soil stabilization, protection against avalanches and landslides, and water filtration. The need to modernize forestry education and unleash untapped potential for women and young people to play a stronger role in achieving the sustainable management of forests was also on the agenda.

Meeting every two years, the European Forestry Commission (EFC) is one of six Regional Forestry Commissions established by FAO to provide a forum for countries to discuss and address forest issues on a regional basis.

© INGER MARIE MULVAD

"Morning in Dyrehaven", shortlisted entry in the European Forest Week "Value of forests" photo competition

© FAO/GIUSEPPE CAROTENUTO

XIV World Forestry Congress session

The XIV World Forestry Congress stressed the need to "invest in a sustainable future"

Approximately 4000 people from 138 countries met at the XIV World Forestry Congress, held in Durban, South Africa, on 7–11 September 2015. The Congress, held on the theme "Forests and people: investing in a sustainable future", was hosted by the Republic of South Africa with the support of FAO. Participants included representatives from civil society, intergovernmental organizations, non-governmental organizations, universities and the private sector as well as around 30 ministers and deputy ministers.

One of the main outcomes of the Congress was the Durban Declaration, which sets out the Congress's vision of how forests and forestry should look in 2050. The declaration outlines a series of actions, including further investment in forest education, communication, research and the creation of jobs, especially for young people. It also stresses the need for new partnerships among the forest, agriculture, finance, energy, water and other sectors, and strong engagement with indigenous peoples and local communities. It further emphasizes the need to integrate forests and trees with other land uses such as agriculture, in order to address the causes of deforestation and conflict over land.

Other Congress outcomes included a message to the United Nations Sustainable Development Summit regarding forests' role in achieving the 17 Sustainable Development Goals (SDGs), a message to the 2015 Paris Climate Change Conference, and a five-year forests and water action plan.

For more information on the World Forestry Congress and the Durban Declaration, see *www.fao.org/forestry/wfc*

The 12th Conference of the Parties of the UN Convention to Combat Desertification focused on the links between land, climate and the Sustainable Development Goals

Held in Ankara, Turkey on 12–23 October, UNCCD COP 12 brought together a number of high-level speakers, including the new COP 12 President, Veysel Eroğlu, Minister of Forestry and Water Affairs of Turkey, UNCCD Executive Secretary Monique Barbut, and Nicolas Hulot, Special Advisor to the President of France.

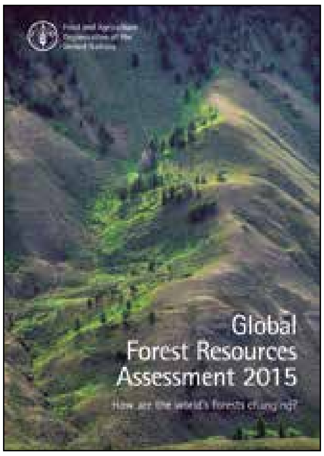
The interlinkages among desertification, land degradation and drought, food insecurity, migration, conflict and political instability were highlighted, with land restoration and afforestation recognized as key parts of the solution, notably via the adoption of voluntary national targets on land degradation neutrality.

An agreement reached at the conference aims to ensure that the amount of healthy and productive land remains stable from 2030. This is a direct response to one of the Sustainable Development Goal targets for 2030, which is to combat desertification and restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation-neutral world. Parties also agreed on the indicators to be used, not only to measure progress, but also to strengthen measures to make the land resilient to climate change and to halt the biodiversity loss that follows the destruction of ecosystems.

Opening of UNCCD COP 12

© UNCCD

BOOKS



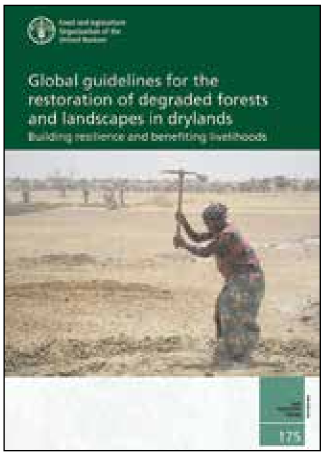
More and better data about the world's forests

Global Forest Resources Assessment 2015 – How are the world's forests changing? 2015. Rome, FAO. ISBN 978-92-5-108821-0.

The contributions of forests to the well-being of humankind are far-reaching. Forests provide vital wood supplies and help to combat rural poverty, ensure food security and provide decent livelihoods; they offer promising mid-term green growth opportunities; and they deliver vital long-term environmental services, such as clean air and water, biodiversity, and mitigation of climate change. Building on data that are more comprehensive and reliable than ever before, covering 234 countries and territories, the *Global Forest Resources Assessment 2015* (FRA 2015) shows encouraging signs of improved forest management and a global slowdown in deforestation. However these trends need to be strengthened, especially in countries that are lagging behind.

FRA 2015 draws upon efforts by the Collaborative Forest Resources Questionnaire (CFRQ), an initiative developed by FAO together with regional data collection partners to jointly collect, analyse and report forest data. The CFRQ covers 104 countries, representing some 88 percent of the world's forests. It is the successful result of the joint commitment of several organizations to simplify and harmonize forest-related reporting while reducing countries' reporting burden. The six partners working to implement the CFRQ for reporting in 2015 are the Central African Forest Commission (COMIFAC/OFAC), FAO Forestry, FOREST EUROPE, the International Tropical Timber Organization (ITTO), the Montréal Process and the United Nations Economic Commission for Europe (UNECE).

Available online: http://www.fao.org/3/a-i4793e.pdf



The role of trees and forests in drylands

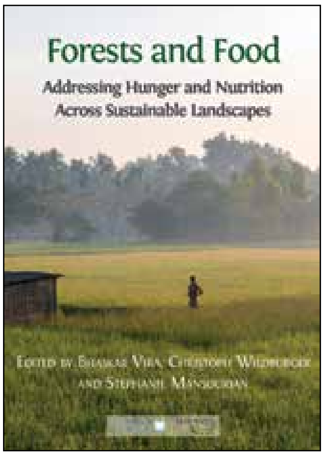
Global guidelines for the restoration of degraded forests and landscapes in drylands – building resilience and benefiting livelihoods. 2015. FAO Forestry Paper 175. Rome, FAO. ISBN 978-92-5-108912-5.

Drylands cover 41 percent of the earth's land surface and are home to 2 billion people. They face extraordinary challenges, including those posed by desertification, biodiversity loss, poverty, food insecurity and climate change. Up to 20 percent of the world's drylands are degraded, and people living there are often locked into a vicious circle of poverty, unsustainable practices and environmental degradation.

These guidelines call for serious efforts to be made to arrest dryland degradation and restore degraded lands. The first of their kind, the guidelines target two main groups – policymakers and other decision-makers, and practitioners – because both have the power to bring about positive change. While they should be tailored to suit regional and local contexts, they present the essential components for the design, implementation and sustainability of restoration initiatives that can help build ecological and social resilience and generate benefits for local livelihoods.

As illustrated by the case studies provided, the guidelines propose a vast range of actions, from on-the-ground activities such as habitat protection, assisted natural regeneration, sand-dune stabilization and planting, to policy improvements, provision of financial incentives, capacity development, and continuous monitoring and learning. Moreover, they show that restoration needs to be considered across the entire market value chain, from seed to end-product, as well as at the landscape level, including the mosaic of land uses, needs and expectations of interest groups.

Available online: http://www.fao.org/3/a-i5036e.pdf



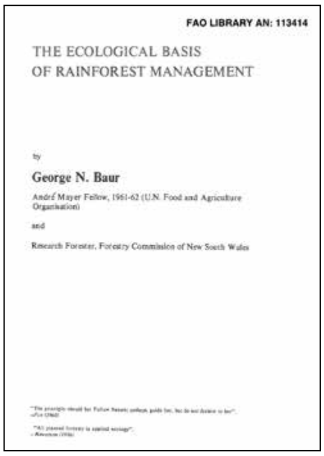
Forests' role in reducing hunger and malnutrition

Forests and food: addressing hunger and nutrition across sustainable landscapes. B. Vira, C. Wildburger & S. Mansourian. 2015. ISBN 978-17-8-374193-9.

As population estimates for 2050 reach over 9 billion, issues of food security and nutrition have been dominating academic and policy debates. A total of 805 million people are undernourished worldwide and malnutrition affects nearly every country on the planet. Despite impressive productivity increases, there is growing evidence that conventional agricultural strategies fall short of eliminating global hunger, as well as having long-term ecological consequences. Forests can play an important role in complementing agricultural production to address the Sustainable Development Goals on zero hunger. Forests and trees can be managed to provide better and more nutritionally-balanced diets, greater control over food inputs – particularly during lean seasons and periods of vulnerability (especially for marginalized groups)—and deliver ecosystem services for crop production. However forests are undergoing a rapid and complex process of degradation, which governments are struggling to reverse.

This volume provides evidence and insights about the potential of forests to reduce global hunger and malnutrition, and the governance approaches that are required. The publication will be of interest to researchers, students, NGOs and government departments responsible for agriculture, forestry, food security and poverty alleviation around the globe.

The book is based on the Global Forest Expert Panel report on forests and food security produced by the International Union of Forest Research Organizations (IUFRO).


FAO LIBRARY AN: 113414

THE ECOLOGICAL BASIS
OF RAINFOREST MANAGEMENT

by

George N. Baur

André Mayer Fellow, 1961-62 (U.N. Food and Agriculture Organisation)

and

Research Forester, Forestry Commission of New South Wales

Tropical forest management 50 years ago

Ecological basis of rainforest management. G. Baur. 1964. Rome, FAO.

This book was published over 50 years ago, but remains of interest today. It was recently digitized so that forest managers, particularly those engaged in forest restoration, can benefit from its exhaustive synthesis of what was known in the early 1960s about rainforest ecology and silviculture. Much of the supporting material that it quotes is from grey literature that is now difficult to locate.

In the early 1960s large areas of natural rainforest still existed across the world's tropics and there was a strong demand for rainforest timbers. Most forestry departments assumed that logging could be made sustainable provided appropriate silvicultural techniques could be developed and applied. This publication reviews the state of knowledge at the time and discusses how it was being used to develop systems to ensure regeneration after logging and boost growth in secondary forest stands. In addition to chapters dealing with environmental conditions, floristics and reproduction, there are chapters concerning some of the more common silvicultural systems then in use. It also discusses enrichment planting when natural regeneration is insufficient and deals with methods of stand treatment to boost tree growth.

Today, there is less forest and much of what remains has been so badly logged it is now highly degraded. Due to corruption and political interference, much of the knowledge described by Baur has not been used. There are large areas of secondary or regrowth forests, as well as degraded lands in which grasses have replaced trees. Management objectives have also changed; rather than emphasizing timber production there is now a greater emphasis on watershed protection, carbon storage or biodiversity conservation.

Baur's review of experiences will provide present-day managers and researchers with useful insights.

Available online: http://www.fao.org/3/a-ax363e.pdf

REDD+ and forest ecosystems in Zambia

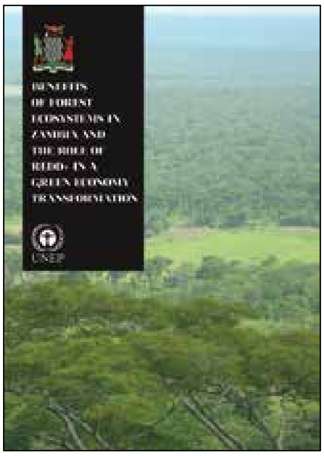
Benefits of forest ecosystems in Zambia and the role of REDD+ in a green economy transformation. J. Turpie, B. Warr & J. Carter-Ingram. 2015. Nairobi, UNEP.
ISBN 978-92-807-3452-2.

Zambia has one of the highest per capita deforestation rates in Africa, despite the key role that forests have to play in sustaining the country's economy and enhancing human well-being. This publication examines the potential of REDD+ to reverse the trend and transition towards a green economy.

It looks into the economic rationale for prioritizing REDD+ implementation by demonstrating the economic benefits of doing so. It assesses the values of forests in the form of wood production (for timber, fuelwood and charcoal) and non-wood forest products, such as wild foods and medicines. It also looks at regulatory and cultural services, such as nature-related tourism, climate regulation through carbon sequestration, retention of sediment for erosion control, regulation of water flow and water quality, and support for agricultural production through pest control and pollination.

The study is expected to elevate the importance of sustainable forest management and conservation in national policy, notably through the national REDD+ strategy.

Available online: http://www.unredd.net/index.php?view=download&alias=14059-benefits-of-forest-ecosystems-in-zambia-and-the-role-of-redd-in-a-green-economy-transformation&category_slug=forest-ecosystem-valuation-and-economics&option=com_docman&Itemid=134



Forests, women and climate change

Mainstreaming gender into forest policies in Asia and the Pacific. 2015. Bangkok, FAO and Center for People and Forests (RECOFTC).

This publication highlights the role of women in national strategies to improve forest management, confirming the key part that they play in managing and protecting forests in the Asian region.

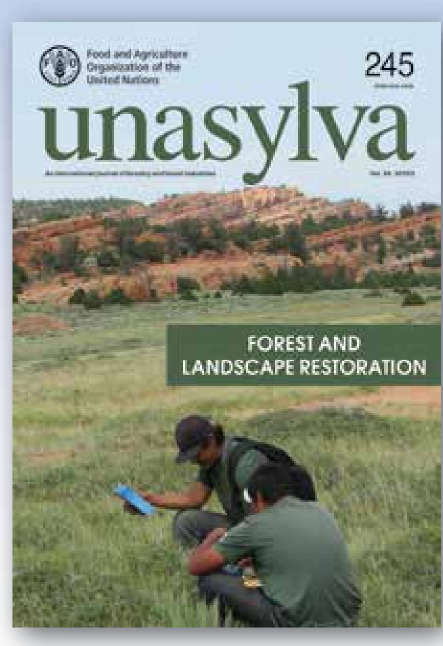
It looks into the way that gender perspectives are integrated into the forest policies of Cambodia, Fiji, Indonesia, Nepal, the Philippines, Sri Lanka, Thailand and Viet Nam, providing a comprehensive overview of each. Nepal and the Philippines provide particularly interesting examples of the integration of gender perspectives into their policies and strategies, despite the challenges they are facing in implementation.

The analysis suggests that having gender-integrated forest policies alone is not enough to reduce pervasive inequalities. Policies must be supported by technical expertise for facilitating implementation and practice. Moreover, clear targets, guidelines, strategies and action plans, supported by adequate budgets and institutional mechanisms in forestry departments and agencies, must be in place so that gender mainstreaming becomes an achievable milestone.

The report provides practical recommendations, such as convening national dialogues and consultation meetings to discuss gender gaps in forest policies and practices and to promote learning networks; conducting gender-sensitive research and developing the capacity of relevant stakeholders; establishing gender working groups; and reviewing and re-working existing management structures to create more gender-balanced forestry institutions and increase women's representation in decision-making. It also recommends the setting up of gender-sensitive monitoring and evaluation systems with gender-responsive budgeting.

Available online: http://www.fao.org/fileadmin/templates/rap/files/meetings/2015/150212_final_report.pdf

Electronic subscription to *Unasylva*



Would you like to continue receiving a hard copy of *Unasylva* or would you rather receive it electronically – or perhaps both?

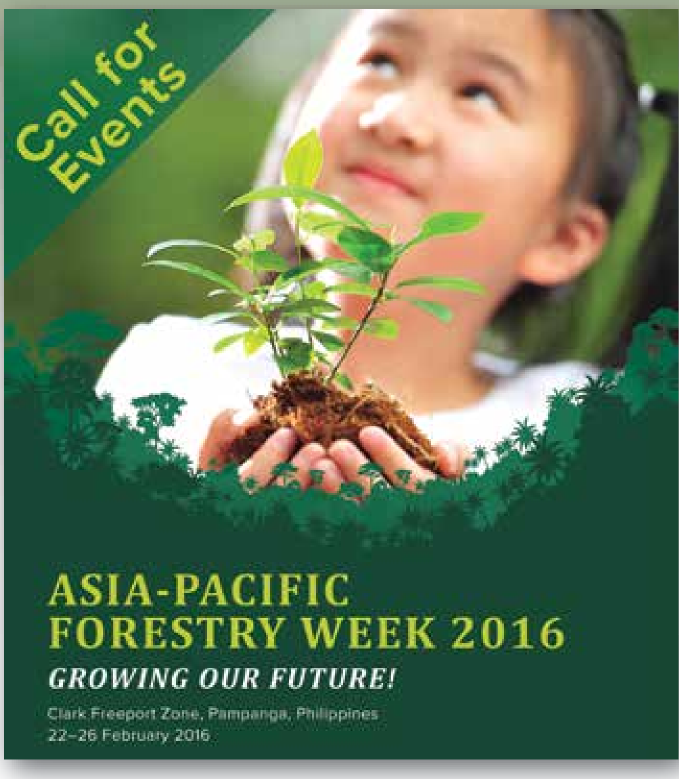
If you wish to substitute your hard-copy subscription for electronic-only, please write to **Unasylva@fao.org** with "Electronic subscription only" in the subject line.

If you wish to receive both a hard copy and an electronic copy, please write to **Unasylva@fao.org** with "Electronic and hard-copy subscription" in the subject line.

Please provide the relevant contact details in the email.

Unasylva will continue to be a free-subscription journal available in English, French and Spanish.

Call for events at Asia-Pacific Forestry Week 2016



FAO and its partners invite people interested in, and committed to, sustainable forest management in Asia and the Pacific to come together for Asia-Pacific Forestry Week (APFW) in Clark Freeport Zone, the Philippines, 22–26 February 2016.

Held in conjunction with the 26th Session of the Asia-Pacific Forestry Commission, APFW 2016 will be one of the most important forestry gatherings in the region in 2016. Organizations with an interest in forestry in the region are invited to run their own partner events during the Week.

Event applications close 15 December.

For more information, go to **http://www.fao.org/about/meetings/asia-pacific-forestry-week/en/**

Food and Agriculture Organization
of the United Nations

Unasylva@fao.org
www.fao.org/forestry/unasylva

I5212E/1/12.15