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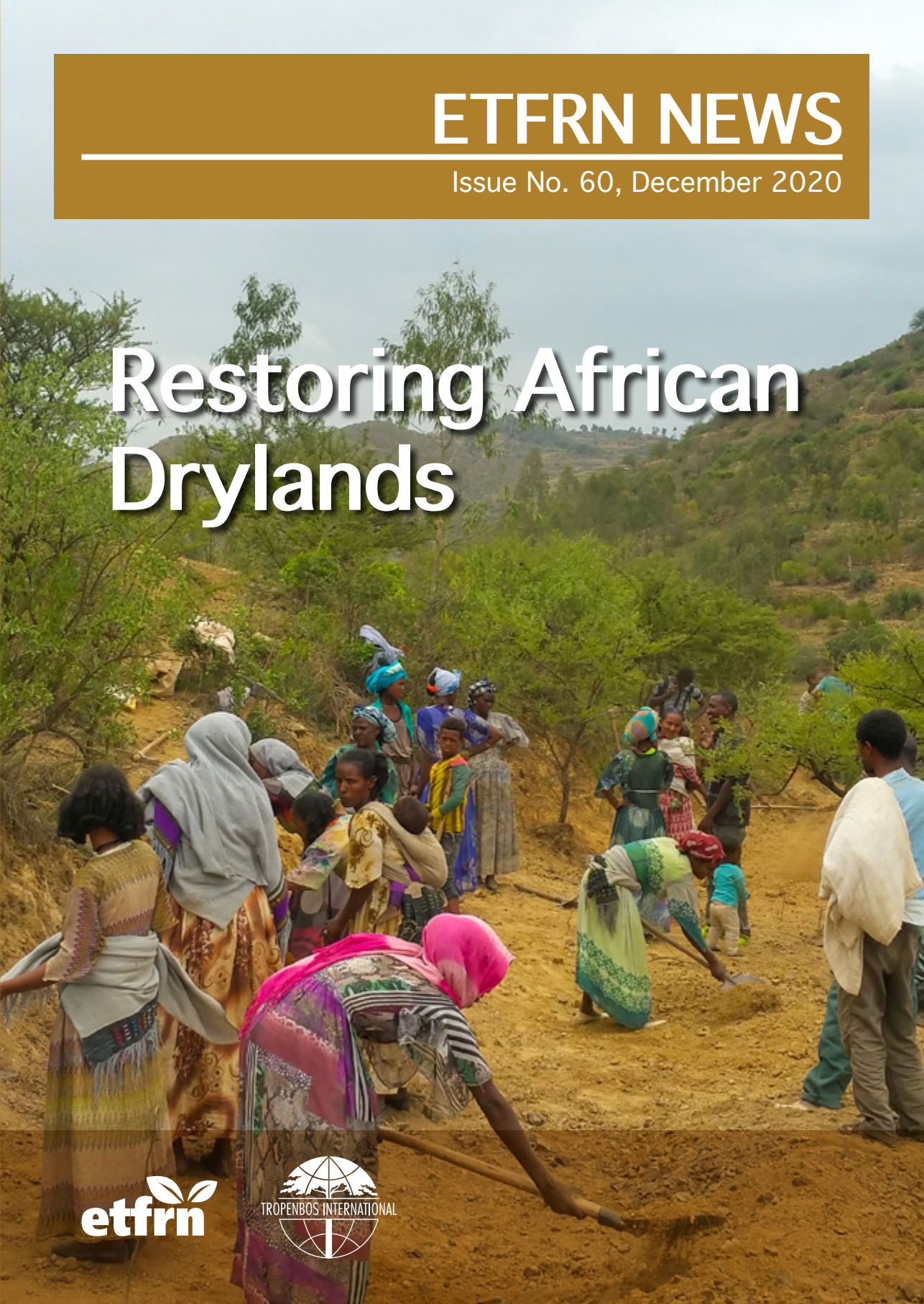
Restoring African Drylands



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Preface

At the beginning of the UN Decade on Ecosystem Restoration, and reflecting the increasing focus on drylands, the topic of this 60th edition of *ETFRN News* is very timely. Drylands cover some 40% of the world's land area and contain some of the most severely degraded landscapes on Earth. They are also home to a third of the world's population including a disproportionate number of the poorest people, along with unique ecosystems and biodiversity. And these issues are more acute in Africa than in any other continent.

This compilation of knowledge on dryland restoration focuses on the Sahel and the Greater Horn of Africa where levels of poverty, land degradation and out-migration are acute. It collates 36 contributions, including interviews from distinguished experts, and many examples of success and hope. These include long-term analyses of remarkable increases in tree cover and improved agricultural yields over large areas of Burkina Faso, Mali, Niger and Senegal that have never before been published, examples of landscape restoration in Ethiopia, and related experiences from Cameroon, Djibouti, Ghana, Kenya, Somalia, Sudan and Uganda.

This work provides new insights into what has led to the clear successes in these regions, summarizes the 'top ten' key findings, and recommends pointers to progress. Large-scale projects have played a role, private sector investments are limited but expanding, but the overriding story is that farmer and community-led initiatives are the main driver of dryland restoration at scale, and at low cost. Simple water harvesting techniques and natural regeneration, combined with locally-managed control over resources have been rapidly adapted and adopted. Key factors to this include bylaws made with and enforced by local institutions and communities, the inclusion of women and youth, and effective national and international policy support.

If the global community are to meet the ambitious commitments by African countries to Land Degradation Neutrality targets, the Bonn Challenge, the African Forest Landscape Initiative and the Great Green Wall amongst others, there is an urgent need to take this knowledge on board in adapting and implementing restoration programmes. But challenges remain, such as tailoring investments to community needs so that local people earn more from their efforts, and the lack of standardized and transparent monitoring to accurately assess progress — not just measured in productivity and hectares, but also in the resulting social, economic and environmental benefits.

In doing so, dryland degradation can be reversed, recreating resilient and productive rangelands, dry forest and agroforestry landscapes that are better adapted to the increased frequency of droughts that are accompanying climate change. And this will also have impacts on mitigation by fixing more carbon, especially in the soil, while restoring lost biodiversity and ecosystem services. Together, we see that restored climate-resilient production systems are encouraging new viable enterprises, creating employment, reducing conflicts and migration, and increasing opportunities to meet the Sustainable Development Goals and the targets of the Rio Conventions on desertification, climate change and biodiversity.

We sincerely hope that the knowledge from the experiences in this volume encourage and enthuse us all, as we work together to redouble of efforts to regreen African drylands, and improve the livelihoods of those living in them.

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ETFRN News to change its name, but not its valued role

— Introducing *Tropical Forest Issues*

The European Tropical Forest Research Network (ETFRN) was established in 1991, prompted by an initiative from the European Commission's Directorate General for Research. It was founded to ensure that research and knowledge activities effectively contribute to the conservation and sustainable use of forest landscape resources in tropical countries, through a network for communication, cooperation and collaboration, by providing services for exchanging of up-to-date knowledge and advocacy support.

But many things have changed in the 30 years that ETFRN has been serving these roles, and it is time to reconsider the network's relevance, focus and function. Whereas its communications-related roles are now superseded in the age of the internet, a survey in 2019 overwhelmingly concluded that *ETFRN News*, its respected flagship publication, remains to this day a highly valued source of knowledge on important forest issues, whatever the future of the network itself.

Tropenbos International, which has hosted the ETFRN Secretariat since 1997 and co-published every edition since, will continue its production and dissemination but now under a new name – *Tropical Forest Issues* – a title that more clearly describes the content, and that will provide the same high quality, relevant, robust, evidence-based knowledge on specific 'hot topics' as it always has.

After 60 editions of *ETFRN News* – all available at www.etfrn.org/publications – we are sure that you will take encouragement from the articles and interviews in the final edition under this title, and the last that will also be printed, reflecting the drop in demand for hard-copy publications.

Expect the next call for abstracts for *Tropical Forest Issues* #61 in early 2021, and we hope that you will continue to contribute, read and benefit from the expert knowledge to be shared.

René Boot
Chair, European Tropical Forest Research Network

Dryland restoration successes in the Sahel and Greater Horn of Africa show how to increase scale and impact

Chris Reij, Nick Pasiecznik, Salima Mahamoudou, Habtemariam Kassa, Robert Winterbottom & John Livingstone

Farmer managed natural regeneration around Rissiam village, Burkina Faso. Photo: Gray Tappan

Introduction

Drylands occupy more than 40% of the world's land area and are home to some two billion people. This includes a disproportionate number of the world's poorest people, who live in degraded and severely degraded landscapes. The United Nations Convention to Combat Desertification states on its website that 12 million hectares are lost annually to desertification and drought, and that more than 1.5 billion people are directly dependent on land that is being degraded, leading to US$42 billion in lost earnings each year. In Africa, three million hectares of forest are lost annually, along with an estimated 3% of GDP, through depleted soils. The result is that two-thirds of Africa's forests, farmlands and pastures are now degraded. This means that millions of Africans have to live with malnutrition and poverty, and in the absence of options this further forces the poor to overexploit their natural resources to survive. This in turn intensifies the effects of climate change and hinders economic development, threatening ecological functions that are vital to national economies.

Chris Reij, Senior fellow, World Resources Institute (WRI), Washington DC, USA; **Nick Pasiecznik**, Dryland restoration coordinator, Tropenbos International (TBI), Wageningen, the Netherlands; **Salima Mahamoudou**, Research associate, World Resources Institute (WRI), Washington DC, USA, **Habtemariam Kassa**, Senior scientist, Center for International Forestry Research (CIFOR), Addis Ababa, Ethiopia; **Robert Winterbottom**, Fellow, Global EverGreening Alliance (GEA), Stoddard, USA; and **John Livingstone**, Regional policy and research officer, Pastoral and Environmental Network in the Horn of Africa (PENHA), Hargeisa, Somaliland.

In response, there is growing momentum for dryland restoration, reflected in national commitments to the Bonn Challenge globally, and in Africa, by the Great Green Wall programme and the African Forest Landscape Restoration Initiative (AFR100). Setting ambitious goals is laudable, but what is increasingly seen is that achieving them will require a change in approach as well as concerted action. At current rates of degradation, it appears that it will take a generation or more for most countries to reach their targets. So, how to speed up the process? And how can scarce financial resources be utilized more effectively? Improving our understanding of restoration successes and documenting the proven approaches, significant outcomes and lessons learned from such successes is a start. This edition of *ETFRN News* adds to the body of knowledge.

The top ten keys to successful dryland restoration

1. **Research results** have confirmed what farmers have learned through practice — that restored farmland increases agricultural yields and diversifies income, leading to improvements in food, fodder and fuel security and many other benefits, even in the short term and in drought years.
2. **Dryland restoration with native species** has had positive impacts on soil fertility, groundwater recharge and availability, and biodiversity, leading to more environmentally and economically resilient landscapes.
3. **Large-scale and centrally managed schemes**, including tree plantations, mechanical construction of soil and water conservation structures and other "top-down" efforts have proved costly, and often suffered from low tree seedling survival and lack of maintenance and follow-up.
4. **Farmer- and community-led restoration** has proved highly successful and in many cases low cost, as have government-led restoration initiatives with community support that provide livelihood benefits; and although private sector investments show great potential, they are currently limited in scale.
5. **Local organizations, institutions and governments** must have their capacities strengthened and be facilitated to discuss, develop and enforce their own local conventions, land-use plans and bylaws governing access to and use of natural resources.
6. **Communities must realize tangible benefits** from restored land and producer organizations can be a valuable entry point, supported by incentives to promote ecologically and economically viable local enterprises.
7. **The role and participation of women and youth**, and other marginalized groups, must be better understood, along with how to support interventions to ensure that they can benefit more equitably from restoration activities.
8. **Institutional and regulatory reforms** at the national and regional level are required to establish more favourable enabling conditions that support locally-led restoration initiatives, and these conditions should be encouraged and supported by international efforts.
9. **Dryland restoration improves carbon sequestration**, but more research is required to quantify increases in soil carbon, with results that will help countries meet their commitments to the Paris Agreement.
10. **Positive outcomes are proven, but issues remain**, such as ensuring truly inclusive participation, enterprise development, capacity building and investment over long time scales, and robust, standardized and transparent monitoring that includes a broad assessment of impacts and trade-offs.

Many development projects and programmes aimed at reversing land degradation have been implemented since the 1980s. Some had positive impacts, although few were integrated or well reported, and unfortunately, many proved to be failures. This edition of *ETFRN News*: Restoring African drylands, collates a selection of articles, briefs and interviews on what has worked in the Western Sahel and the Greater Horn of Africa, along with related initiatives and cross-cutting issues. This collection of information highlights the reasons behind restoration successes and identifies critical actions to increase smallholder and community participation in effectively scaling up these proven approaches to dryland restoration.

With the right support and workable strategies in each country for scaling appropriate, low-cost and effective restoration practices — backed by adequate resources for implementation — there is great potential for rapid poverty reduction, increasing ecological and economic resilience, and climate change mitigation through carbon sequestration. And by ensuring that such strategies are put into practice, governments and donors will better support the regreening of African drylands, and make great and much-needed progress in meeting Rio Convention targets and the Sustainable Development Goals.

The urgency for action

Over the past 50 years, rapid population growth, extreme weather events and the resulting decrease in tree cover saw farmers across the Sahel and the Greater Horn of Africa lose their fallow-based soil restoration systems. This led to land degradation, declining soil fertility and lower yields. The lost trees had also served as a critical safety net during crop failures and other shocks. Increasing population pressure, climate change, poverty and conflict mean that many countries are facing a critical problem.

Niger, for instance, regularly experiences drought years, but the 2020 rainy season was characterized by high rainfall, and floods occurred in many parts of the country, destroying crops and homes and damaging infrastructure. The country faces terrorist attacks from ISIS and Al Qaida-affiliated groups on its borders with Burkina Faso and Mali and from Boko Haram in the southeast. It currently has a population of about 22 million people, and with an annual demographic growth of 3.6%, its population will increase to 33 million people in 2030. Rainfed farming is largely concentrated in a small area in southern Niger along the border with Nigeria, where some regions (Maradi and Zinder) already have high rural population densities (100+ people/km^2). In the absence of urban employment opportunities, it is hard to imagine how millions more will be able to make a living in these rural areas.

Despite all these challenges, there are signs of hope. One of them is that since the mid-1980s, hundreds of thousands of smallholder family farmers have increased the number of trees on the land that they manage — not by planting them, but by protecting and managing those that regenerated naturally from rootstocks or seeds. Farmers have achieved this increase over many millions of hectares across densely populated parts of southern Niger, which makes it without doubt the greatest positive environmental transformation in Africa. Smallholders have literally been building "great green productive landscapes," and lessons can be drawn from these regreening experiences for scaling up within and beyond these regions.

Experiences described in this edition show that many countries have had restoration successes and most of these successes are based on farmers and local communities using simple water-harvesting

structures and techniques for regenerating trees and shrubs. This effectively restores severely degraded land, regreening landscapes by increasing the number of trees. The challenge is how to rapidly scale these up and out. Most countries and donor agencies have not yet developed or implemented effective restoration scaling strategies, which makes it unlikely that the very ambitious restoration targets made for 2030 can be met. Given the urgency of the situation, it is vital to accelerate implementation. And this can be done if millions of smallholders and pastoralists in the drylands are mobilized to invest their scarce resources in efficient, sustainable and easily replicable restoration techniques, and if they see that they can benefit quickly and equitably from the improvements that are a clear result of their efforts.

The aim of this edition of *ETFRN News* is to draw the attention of national and international practitioners, policy makers, social and mainstream media to restoration successes in dryland Africa. It identifies the drivers and enabling factors behind these successes and draws lessons on how they can be scaled out, especially in the context of the current momentum for landscape restoration in worldwide.

This review article briefly describes the major land restoration commitments and progress in achieving them, especially those related to the Bonn Challenge, the Great Green Wall and the African Forest Landscape Restoration Initiative in the Sahel and Greater Horn of Africa regions, which are the focus of this edition. It summarizes the articles and other contributions by section, and then presents lessons learned, conclusions, recommendations, and a call for action.

Restoration commitments and progress

It is encouraging that in the last 15 years, major national and international restoration commitments have been made, and restoration is much higher on the policy agenda. We now also note the start of the UN Decade of Ecosystem Restoration (2021–2030) adopted by the UN General Assembly on 1 March 2019 (UN 2019). There are three main initiatives affecting Africa: the global Bonn Challenge, the African Union's Great Green Wall, and the African Forest Landscape Restoration Initiative. Other major initiatives are not discussed in this synthesis, though they often overlap and support these three programmes. They include the UNCCD's Land Degradation Neutrality programme, the World Bank's African Resilient Landscapes Initiative, and FAO's Action Against Desertification. In addition, the New York Declaration on Forests includes among its ten goals the aim of restoring 350 million hectares of degraded forest land by 2030. Also not discussed here are past commitments, such as the UN Decade for Deserts and the fight against Desertification (2010–2020) that has just ended, with as yet no statements regarding its achievements.

The Bonn Challenge

The Bonn Challenge is a non-binding initiative launched in 2011 by the Government of Germany and IUCN, which strives to convince governments, NGOs and the private sector to commit to restoring degraded land and deforested landscapes. The global target is to restore 150 million hectares by 2020 and 350 million ha by 2030. By 2017, governments had committed to restoring in excess of 150 million ha, and in 2020, more than 70 pledges from more than 60 countries collectively aimed to restore 210 million ha. The Bonn Challenge website provides data regarding all the pledges, but at the time of *ETFRN News* going to press (December 2020), estimates of restoration achievements were available for only five countries globally, with Rwanda the only African country to provide data.

What is restoration?

The Bonn Challenge defines forest landscape restoration (FLR) as "the ongoing process of restoring the ecological functionality of degraded and deforested landscapes while enhancing the well-being of people who coexist with these places" on its website. Other organizations expand on this. The Global Partnership on Forest and Landscape Restoration (GPFLR) adds that, "FLR is not an end in itself, but a means of regaining, improving, and maintaining vital ecological and social functions, in the long term leading to more resilient and sustainable landscapes," and the International Union for Conservation of Nature (IUCN) states that "FLR is more than just planting trees – it is restoring a whole landscape to meet present and future needs and to offer multiple benefits and land uses over time."

This question is further complicated by different understandings and definitions of the component terms. First, what is a forest? This seems to be a simple question, but it is not. FAO defines a forest as "land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ" (FAO 2020). But many people would hardly consider land that is 90% free of tree cover as a "forest." There are also many different definitions of "landscape" and its related terms (e.g. Scherr et al. 2013). And the definition of what FLR is trying to reverse; i.e., land degradation, is another issue. The UNCCD definition is complex indeed (Article 1: Use of terms, p. 4). Thankfully, that of IUCN is explained in clearer terms, as: "a reduction or loss of the biological or economic productivity and complexity of land. In drylands, land degradation is known as desertification" (IUCN 2015).

Throughout this edition, the term "restoration" is used to imply an increase in the productive capacity of land, which is often expressed in terms of increased plant production and vegetative cover. This is usually associated with increases in crop yields, and also with increases in the number and diversity of trees, shrubs and other plants, leading to improved livelihoods for those living in restored landscapes.

The Great Green Wall

The Great Green Wall (GGW) is Africa's flagship programme, launched by African heads of state in 2007. Agreements were signed with 11 countries in 2010 to combat the effects of climate change and desertification across the Sahel and the Horn of Africa. The Pan-African Agency was created to coordinate implementation and support the mobilization of resources. The original idea was to plant a belt of trees at least 7,000 km long and 15 km wide from Senegal to Djibouti in areas that receive between 100 and 400 mm of mean annual rainfall. But around a decade ago, there was a change in concept. The geographic focus to be covered broadened, with the total intervention areas of all 11 countries now 156.1 million hectares (Mha) (UNCCD 2020). The goal of the GGW also evolved, from planting a green belt to supporting an integrated ecosystem management approach in the targeted areas. This would include a mosaic of various land uses and production systems that incorporate sustainable dryland management and restoration, regeneration of natural vegetation, and associated soil and water retention and conservation measures (UNCCD 2020).

But as reported by UNCCD (2020: p36), "As of early 2020 — considering all activities that may be contributing to the GGW Initiative, applying the wider scope and definition of the GGW, and accounting

for the regional and cross-border projects and programmes, a total of 17.8 Mha land is under restoration or has been rehabilitated in GGW member states. To reach a total area of 100 Mha by 2030, it would be necessary to substantially increase the current pace of land restoration from 1.9 Mha/year on average to 8.2 Mha annually." The report adds that "land restoration in Africa incurs an average cost of USD 440/ha across all activities and countries, although such costs are likely to be higher within countries of the Sahel region. Land restoration costs for existing projects in the region such as the SAWAP [Sahel and West Africa Program] reach an average cost of 530/ha. Applying these basic estimates to the remaining land area in need for restoration to reach the 2030 vision would mean that land rehabilitation measures alone would cost between USD 3.6 and 4.3 billion per year, or a total that varies between USD 36 and 43 billion up to 2030" (UNCCD 2020: p36).

The African Forest Landscape Restoration Initiative

Ten African countries launched the African Forest Landscape Restoration Initiative (AFR100) in 2015 to restore 100 million ha by 2030. By 2020, 30 African countries had pledged to restore 125.7 million hectares. AFR100 contributes to the Bonn Challenge, the African Union Agenda 2063, the Sustainable Development Goals, and other targets. Supported by more than 40 technical and financial partners, in its first five years the initiative has focused on mobilizing countries and partners, piloting activities, building capacities, and creating a strong international standing and recognition, as explained by the AFR100 Coordinator, Mamadou Moussa Diakhité in Section 4. Restoration assessments have been completed in 18 partner countries using the Restoration Opportunities Assessment Methodology (ROAM) tool developed by the World Resources Institute (WRI) and the International Union for Conservation of Nature (IUCN). WRI's Global Restoration Initiative has also trained and supported a cohort of young African restoration entrepreneurs through its Land Accelerator programme.

The AFR100 website does not yet include data about progress made in achieving its targets. A monitoring working group was established in 2020 to develop and roll out a comprehensive system to track restoration efforts and measure socioeconomic impacts, as AFR100 increases its emphasis on implementation and scaling. However, the Covid-19 pandemic and resulting restrictions halted this effort. The aim for 2021 is, come what may, to establish a robust system that ensures that information from all partner countries is collected in a systematic and standardized manner and analyzed and reported, leading to the first comprehensive AFR100 Report on the State of Restoration in Africa.

Farmer and community-managed restoration

Section 1 includes examples of successful restoration led by farmers and communities across the Western Sahel and Ethiopia. People who believe that little or nothing has changed despite decades of investment must read these case studies. Hundreds of thousands of farmers in Niger, for example, have protected and managed the woody species that regenerate naturally on their farmland over five million hectares, making it the largest restorative transformation in Africa [1.9].

Hundreds of villages in Senegal's densely populated "peanut basin" now have many more trees than 30 years ago. In two villages surveyed, tree cover and density on farmland doubled in that time period, while protection of and regeneration in community grazing lands have transformed them from degraded shrub to dense wooded savanna with 61% cover [1.1]. A key conclusion from this article was that these sustained increases from locally controlled initiatives are in stark contrast to the limited longer-term impacts from many large, centrally managed projects that funded infrastructure investments and disparate activities rather than focus on capacity building in rural communities.

Yacouba Sawadogo is an innovative farmer in Yatenga, Burkina Faso, who demonstrated how to improve traditional *zaï* planting pits. This technique has been widely adopted, and he received the 2018 Right Livelihoods Award for his impact on restoring degraded land in the Sahel. On 11 December 2020, the United Nations Environment Programme announced that he is one of the laureates of the 2020 Champions of the Earth Award, the UN's highest environmental honour.

This is confirmed elsewhere in Senegal, where World Vision field staff reported in 2019 that more than 20,000 farmers across 45 communes in Kaffrine, Fatick and Kaolack regions had been trained in farmer managed natural regeneration (FMNR), managing an average of 40 trees/ha [1.6]. Between 2015 and 2020 the area under FMNR in Kaffrine Region alone increased by almost one-third to 85,000 hectares, as farmers saw the benefits of these practices, and were supported by training and extension. Furthermore, with no costs for nurseries, transport, planting or fencing, FMNR is estimated to cost only US$50/ha, whereas tree planting costs US$500/ha or more and typically suffers from low survival rates. The most common trees regenerated and managed by farmers include *Balanites aegyptiaca, Combretum glutinosum, Faidherbia albida, Piliostigma reticulatum* and *Ziziphus mauritiana*. They provide poles, firewood, fodder, fruit, oil seeds, honey and medicine; with some farmers earning an additional US$170–340 per year from tree products alone. Trees also improve soil fertility and crop yields. Research shows a more than 2.5-fold increase in cereal production, from 296 to 767 kg/ha, related to increased soil organic matter [3.5].

In Mali, Bankass and neighbouring districts on the Seno plain were a largely treeless landscape in the 1980s. But with the promotion of FMNR since the early 2000s, the regrowth of trees covered an estimated 450,000 hectares by 2010, with tree densities of more than 250 trees/ha, mostly on rainfed millet fields and in short-term fallows [1.5]. By 2019, 90% of the farmers interviewed were practising FMNR, a 50% increase over 20 years. The planting of trees was limited by a lack of water, but farmers who adopted FMNR increased tree cover on their farmland to an average of 277 trees/ha. The data

collected showed that restored land was dominated by *Combretum glutinosum* (82%), with *Gueira senegalensis* and *Balanites aegyptiaca* making up a further 10%. In the neighbouring Koro District, *Faidherbia albida* dominates on land restored through FMNR. Farmers noted that of the 49 species of trees, grasses and wildlife they identified as most useful to them, 35 had become more common. Farmers also noted increased millet yields, due to protection against winds and to enhanced soil fertility, and that so much more grass and foliage was available for livestock in the dry season that a surplus could now be cut and sold. FMNR also reduced the time needed for women and girls to collect fuelwood, since they could use the pruned branches from trees. It was also important that farmers noted fewer conflicts between villagers over natural resources, and that stronger relationships had developed, with a key factor being local institutions that are respected and effective.

Similar cases were seen in Burkina Faso's Yatenga Region [1.4] and Niger's Tahoua Region [1.2]. Both faced droughts and food shortages in the 1970s and early 1980s. But investments in simple water harvesting techniques in the mid-1980s — including improved traditional planting pits (*zaï*), half-moons and contour stone bunds — restored land productivity and recharged groundwater levels. Both regions are now much greener and all their wells have water year-round, along with new vegetable gardens that even produce a surplus for sale to neighbouring villages. In Niger, project funding ended in 1995, but farmers further expanded the restored areas using these easily replicable techniques, especially planting pits. As in Yatenga, vegetables are now grown on what was a barren plateau 30 years ago.

Farmers across the Sahel have always had to cope with droughts and famines. In recent decades they have now also faced more extreme weather events, even in years of "normal" rainfall. A review of experiences in Niger shows that an increasing range of techniques helps farmers adapt to the impacts of climate change [1.7]. These include water harvesting techniques and FMNR, mulching to conserve humidity and control weeds, use of early maturing crop varieties, and crop rotation — developing their own climate-smart agriculture. Simple water harvesting practices introduced in the early 1980s, and FMNR, introduced in the 1990s, helped farmers build resilience to climate change and to harvest crops even in drought years, with increased number of trees on their farms that produce fodder, fruit and fuel that they use or are also able to sell.

In Senegal, researchers have also developed a "climate-smart village" approach. It is based on strengthening local governance of natural resources, in combination with promotion of agroforestry, planting fruit and fodder species, FMNR, and management of inter-village pastoral areas, among other practices [1.8]. This has not yet been applied at scale, but has the potential to do so, and it shows how researchers working closely with land users can make a difference, and how communal pastoral areas can be restored.

Northern Ethiopia — greener than it has been during the last 140 years — is a remarkable example of large-scale transformation (Nyssen et al. 2009). This is illustrated by the story of a village in Tigray Region that was considering relocating in the mid-1990s due to severe land degradation, but is now an award-winning showcase for the results of restoration [1.3]. Of the 6,766 ha of Abreha We Atsbeha watershed, most of which was comprised of severely degraded rangelands, 69% was restored using area exclosures, and 1,500 ha were reforested. The rest of the watershed was restored using assisted natural regeneration supplemented by terracing, contour bunds and other techniques to conserve soil and water. An additional 899 ha of farmland was restored, and following the construction of

Natural regeneration in Burkina Faso, with crop residues stored in the trees for dry season fodder.
Photo: Gray Tappan

55 check dams and associated regreening, this improved groundwater recharge, and increased the irrigable portion of the watershed to 450 hectares.

The experience of area exclosures from Tigray is just one example of rangeland "rehabilitation," as it is often called (rather than "restoration"). This also includes rotational grazing, reseeding and building bunds and water diversion channels, among a wide range of other techniques. These techniques, whether alone or in combination, improve rangeland resilience and productivity, which leads to higher livestock production and improved pastoral livelihoods (e.g., Behnke et al. 1993; Liniger and Mekdaschi Studer 2019). Another example of the successful restoration of grasslands, from Kenya, is also detailed [2.6].

Private-sector and project initiatives

Innovative private enterprises

There are few examples of dryland restoration that have been led by the private sector. But Section 2 starts with one, which built on the successes of FMNR in Niger. Sahara Sahel Foods was established in 2014 as a social enterprise to improve livelihoods by processing and marketing products from indigenous trees. Overcoming many constraints on the way, today it purchases some 80 tonnes of produce annually, paying €18,000 to 1,500 collectors, mostly women, from 70 villages, employing 21 permanent staff and 300 to 400 women as temporary workers [2.1]. Fruits, nuts and leaves are collected from more than 20 indigenous species; they have different production cycles, so work lasts year-round. Six of its products have won awards, including the Prime Minister's Award in 2017, showing that it is possible to create acceptance for foods once considered as "only for the poor."

A farming planting a baobab (*Adansonia digitata*) seedling in his farmland in Kaffrine, Senegal.
Photo: Sidy Diawara

Another innovation is Seedballs Kenya, pioneering a method for efficient and low-cost reintroduction of tree and grass species into degraded areas in East Africa [(ii)]. Seeds of native trees and grasses are coated in waste charcoal dust mixed with nutritious binders, which protects them from predators until rains arrive, and encourages germination. Spread by hand, slingshot, crop-spraying planes, helicopters or drones, for as little as US$0.05 per established seedling, this greatly reduces costs compared to planting seedlings.

Forest and farm producer organizations

The largest private sector in the world is probably the aggregate total of all smallholder producers, informal and often unrecognized associations, and small – and medium-sized enterprises – together referred to as producer organizations (Pasiecznik et al. 2015). And although many of these groups came together spontaneously, many have greatly benefitted from project support. Building on experiences, interviews and local surveys in Ghana's savannah zone, producer organizations changed theirs practices and have rebuilt climate-resilient landscapes ensuring that local communities benefit through restoration [2.3]. In meeting restoration targets these groups are often overlooked, in spite of the fact that they offer logical entry points for effective actions to restore degraded landscapes, provide platforms to demonstrate and lobby for improved tenure systems and access rights, motivate implementation, facilitate access to markets and capital, and offer capacity-building services for members. But in Ghana, as elsewhere, they face challenges such as limited technical knowledge, unfavourable tenure arrangements, limited involvement in landscape planning and decision making, and lack of financial support. Policy makers must acknowledge the significant local knowledge and expertise of these groups and ensure that they are included in dialogues on national restoration agendas.

The exploitation of gum arabic in Sudan provides smallholders with up to 38% of their annual income, although with limited access to finance, they sell their gum for low prices to village traders. The Structuring the Gum Arabic Sector pilot project in North Kordofan State (2014–18) introduced transparent contracts that paid producers the competitive auction market price [2.5]. Organizing producer groups also enabled smallholders to increase the quality and quantities sold, attracting buyers who were willing to pay a premium. This led to a new proposal: Gums for Adaptation and Mitigation in Sudan. Many public-sector donors say they appreciate efforts to involve the private sector, producer groups or larger companies, but projects that include them often lead to concerns that public funds may subsidize activities that could be funded through private investment, or could make powerful companies take advantage of small-scale producers. This was avoided in Sudan by using public funds only for capacity strengthening for producer groups and by facilitating interactions with commodity buyers and microfinance institutions.

Commercial plantations

There have been significant efforts globally to promote dryland afforestation, but they have had mixed results (FAO 2015). Evidence indicates that positive results can be achieved from participatory planning and implementation, empowering local communities, capacity building, and securing land-use rights. In Uganda, the Sawlog Production Grant Scheme became the country's first private-sector forestry initiative in 2002, supporting smallholders and medium-scale farmers to invest in timber plantations. This included provision of seedlings and money: around US$250 per ha towards planting costs [2.2]. The third and current phase includes a campaign to promote afforestation in Karamoja, the driest part of the country (400–700 mm mean annual rainfall), through demonstration sites and training courses. Convincing communities of the economic benefits was the overriding factor in success, with financial incentives to trigger interest. But subsidies alone are not enough, and innovative financing models — such as credit financing and low-interest loans with long repayment periods — are needed.

Experiences in Tigray, Ethiopia, showed that seedling quality and management matter in successful dryland restoration, and that research can help to improve tree planting techniques and post-planting care to increase survival rates. Participatory community and private-sector models will also help to resolve issues related to trade-offs between plantations and sustainable livelihoods [2.4]. In the same region research showed that the drought-tolerant and fast-growing Australian *Acacia saligna* can also generate income for smallholders, with farmers selecting two ecotypes that best met their needs [(iv)].

Developing sustainable charcoal value chains

Charcoal production is a key driver of dryland deforestation and degradation, and promotion of sustainable initiatives is an urgent priority. Two examples show how projects are supporting this aim. In the driest part of Cameroon. Sustainable wood fuel value chains are an important component of restoration, and an initiative in the Far North Region is defining and testing options to manage trade-offs between social and ecological impacts and transboundary trade [(v)]. In Ghana, charcoal production and sale is a major source of income for local people, traditional authorities and local and national government [(iii)], but effective new policies at the national and regional level need to be developed, with the participation of all stakeholders, in order to reduce environmental impacts and promote dryland restoration.

Restoring rangelands

Dryland restoration is often associated with increasing tree cover, but improving the productivity of grasslands and pastures is also an important component. An example from the Rift Valley in Kenya shows what can be achieved by one organization's long-term efforts to demonstrate that sustainable pasture restoration is possible, and that it can improve livelihoods and food security while also reducing conflicts. Their tried and tested methods are being widely replicated by the government and NGOs, and most importantly, by pastoralists themselves [2.6]. Stakeholders are consulted and involved at every stage, with special attention paid to youth, women and cultural norms. The approach facilitates restoration in response to community requests on a cost-sharing basis by providing training and advice, with 2,400 hectares of grasslands restored, resulting in significant increases in farm incomes. Carbon sequestration is another, often hidden, benefit. The organic carbon in the top metre of soils worldwide is more than all that is held in the atmosphere and vegetation combined, and research shows that after 20 to 30 years, restored grasslands contained 45 tonnes of soil organic carbon per hectare, 50% more than degraded areas did (FAO 2017).

Cross-cutting issues

Empowering farmers and their communities

The chances of restoration succeeding in African drylands are greatly improved when local communities, institutes and governments are empowered to work together in planning and implementing conventions and bylaws that define the rules, sanctions and enforcement for managing resources [1.3; 1.8]. In Burkina Faso and Niger [3.1], 17 local conventions at the commune (rural district) level now support sustainable landscape use, strengthen responsive decentralized governance, and reinforce rights and responsibilities. This has led to improved resource management, increased FMNR, and, most importantly, has reduced violent conflicts by an average of 74% in targeted communes.

An example from Ghana shows that achieving equitable resource governance in FMNR requires a shared vision for restoring landscapes [3.2]. Mapping local-level power dynamics related to resources helps mitigate potentially inequitable outcomes, especially with communally managed forests and pastures. Also, all land users, including pastoralists, must participate in decision-making processes. Asking "by whom and for whom?" is important, as well as "where?" — which affects upscaling and who can participate. But the key is strengthening resource governance by supporting community-led, inter-community collaboration, with cross-jurisdictional and cross-sector support from government, traditional institutions and NGOs.

Focus on women and youth

Participation is the core of sustainable restoration. But there are many definitions of the term, and neither they nor the indicators needed to measure them are clear [(vi)]. Externally led initiatives are still being designed and implemented where "local participation" is hardly more than mere rhetoric. Women and youth are often involved in the hard work of restoration, but are not always the main beneficiaries. In contrast, they benefit from more farmland trees, which reduces the time needed to collect firewood (Reij et al. 2009). In addition, with groundwater recharge following water harvesting structures [1.2; 1.4], nearby wells are full again and the long march to faraway water sources has become a thing of the past.

Women also face constraints to implementing restoration practices as they do not have the same rights and resources as men due to entrenched gender norms. Gender is an important part of

Training in tree establishment techniques for women in Rigal Saude, Niger. Photo: Sahara Sahel Foods

determining who does what, who makes which decisions, who has access to resources and who benefits from restoration initiatives. An excellent analysis in Burkina Faso [3.3] analyzes gender differences and inequalities in rights and responsibilities, and sees that women find innovative ways to participate, such as collective action and mutual support groups. Ultimately, however, it is the quest for land security and economic opportunities that drives improvements to women's living conditions and their engagement. Other projects promote youth involvement in restoration, such as in Ethiopia, where youth are now leasing and managing nurseries and plantation sites, giving them control over the forests they are planting [(vii)].

Dealing with the paradox of too many trees

The invasion of woody weeds, both exotic and indigenous, is a serious issue over many millions of hectares in dryland Africa, and their impacts certainly meet the definition of land degradation: "a reduction or loss of the biological or economic productivity and complexity of land" (IUCN 2015). *Prosopis* species are by far the most dominant invasive exotic trees in tropical African drylands, covering an estimated 12 million hectares in the Greater Horn, and double that area across the continent [3.4]. Of the many indigenous invaders, *Acacia* species are the most common, affecting more than one million hectares in southern Africa, and now also spreading in the Greater Horn [viii)]. This is not an insignificant issue.

"Control by utilization" for fodder, charcoal and other tree products is increasingly seen as the answer. Advances in recent years have created new enterprises and more resilient agroforestry systems [3.4]. Proliferation of woody weeds also enhances above-ground and soil carbon stocks, but these impacts require further research. Improving the management and use of these species will help overcome the challenges of food, fodder and fuel insecurity, rural unemployment and migration, land degradation,

and climate change adaptation and mitigation, and can generate benefits on a huge scale. But this requires support to develop new markets and viable enterprises based on value-added products from invaded land that has been profitably restored and converted to drought-proof agroforestry systems that meet local needs.

Soil fertility and water availability

Soil and water are the fundamental basis of life, and the final two papers in Section 3 look at their interactions with dryland agroecosystems. Increasing soil productivity and reducing vulnerability requires overcoming a complex web of challenges. Research in Burkina Faso, Niger and northern Togo [3.5] revealed the crucial role of soil organic matter in maintaining soil fertility, with positive effects on yields and fertilizer-use efficiency, particularly on sandy soils. Most benefits come from humus, which binds the soil. Since humus can hold many times its own weight in water, it is very effective in retaining moisture, especially in sandy soils during dry periods. The loss of fallows due to agricultural intensification, and the use of crop residues for fodder and fuel, had led to decreasing inputs of organic matter. Farmers realized the value of trees as providers of large amounts of leaf biomass as well as other services. Millions of farmers have promoted the regeneration of trees, especially *Faidherbia albida*, known across the Sahel as the "fertilizer tree." Research over many years has shown a doubling of soil organic matter under tree canopies and a doubling of crop yields, as well as fodder and fuel provided by trees.

Water, or the lack of it, is the principal factor defining drylands. Yet the impacts of tree cover on water are often neglected or misrepresented in discussions and studies of forest landscape restoration [3.6]. Decision support tools tend to focus on tree products and ecosystem services, whereas investing in increased tree cover needs to account for wider implications, especially in terms of water. Tree cover has considerable potential for improving water security, but there is still a need for more research in order to tailor guidance to local needs and contexts. The protection and restoration of natural vegetation are nonetheless likely to provide more benefits than alternatives, as natural ecosystems have evolved as effective systems for conserving water. Local observations should be recognized.

International actions and intentions

The ongoing Regreening Africa programme (2017–2022) aims to restore one million hectares and improve the livelihoods of half a million smallholder farmers across eight African countries (Ethiopia, Ghana, Kenya, Mali, Niger, Rwanda, Senegal and Somalia) through a bottom-up transformation of degraded lands [4.1]. Survey data, alongside real-time monitoring, show that FMNR is the most commonly adopted practice, with uptake ranging from 48% in Rwanda to 94% in Niger. Next most common is tree planting, with uptake ranging from 47% in Niger to 82% in Rwanda. This article offers valuable information about other impacts, which also vary by country. The project team is now reviewing approaches to scaling to better address existing barriers, aiming to promote learning and behavioural change so that more households will adopt land restoration within project sites.

The Drylands Development Programme (DryDev) was a six-year initiative ending in 2019 that facilitated restoration in Burkina Faso, Ethiopia, Kenya, Mali and Niger. It used the "options by context" approach to promote interventions prioritized by smallholders that were informed by local realities and by the integration of local and expert knowledge. Article 4.2 focuses on achievements in Ethiopia and Kenya, where some 80,000 smallholders were engaged in applying various interventions. The main lessons were that success depended on access to high-quality seedlings and to technology and finance; appropriate policy and institutional mechanisms that facilitated community participation,

tailoring interventions to local contexts and co-learning with farmers; and access to extension services through producer organizations. Options must also be affordable, generate tangible benefits to encourage participation, and be supported by farmer-to-farmer extension. Large, integrated and long-term investments are critical for impact at scale, requiring public–private partnerships to promote innovations and leverage resources to help expand beyond the project's target landscape.

Interviews

Complementing the articles are interviews with four experts. They are: Dennis Garrity, Chair of the Global EverGreening Alliance and former Director General of ICRAF; Mamadou Moussa Diakhité, Coordinator of AFR100, hosted by NEPAD; Elvis Paul Tangem, Coordinator of the African Union's Great Green Wall in the Sahel and Sahara Initiative; and Nora Berrahmouni, Senior forestry officer with FAO at the Regional Office for Africa. They were asked to address three common questions.

What has worked and not worked regarding landscape-level restoration"
The answers to this question bore many similarities. Garrity emphasized the need to build on previous successes and foster grassroots movements to drive the spread of restoration solutions. Tangem stated the need to build on indigenous knowledge, experiences and leadership. Berrahmouni supported regenerative restoration efforts such as FMNR that have proved to be cost-effective and should be used wherever possible. Diakhité noted that national and sub-national assessments of restoration opportunities have created an awareness that forest landscape restoration is more than just planting trees. And there was consensus that engaging communities is at the heart of restoration.

What priority interventions would trigger and accelerate the scaling up of restoration?
Here the answers showed some differences, but shared an urgency to increase restoration actions, which require innovative forms of funding. Diakhité emphasized the need to mobilize private investors, including small- and medium-sized businesses, to kickstart forest landscape restoration, develop agroforestry and agricultural value chains, and tap into carbon funds for upscaling. Tangem also suggested actions to encourage involvement by private businesses and impact investors, and would like to see new sources of restoration funding such as investments by pension funds, and also through green bonds and carbon certificates. Berrahmouni advocated large, long-term public and private-sector investments, which must include a value chain approach. Garrity highlighted the creation of the Global Evergreening Alliance. It now has 50 members, including most of the major development and conservation organizations that have pledged their joint capacity to restore millions of hectares of degraded land through the spread of tree-based systems; this should lead to the capture of 20 billion tonnes of CO_2 annually by 2050.

What can governments, the UN, donors and regional agencies do differently or additionally to further restoration?
Berrahmouni proposed avoiding investments in small, scattered, short-term projects and favoured support for the Great Green Wall initiative, underlining the importance of developing sustainable and resilient value chains for landscape products and ecosystem services.

Tangem pointed out that the Great Green Wall still has not received the US$4 billion promised at COP 21 and suggested that donors should fund long-term and large-scale transboundary projects. Diakhité noted that AFR100 spent its first five years mobilizing countries and partners, piloting activities and building capacities, and will now shift to implementation, scaling and tracking restoration efforts and their impacts. He felt that there is a lack of information regarding potential funding opportunities, and that those who implement restoration should develop bankable projects that they can successfully "sell." Garrity emphasized the need for governments and development organizations to drastically change their mindset and switch from top-down to bottom-up approaches, recommending that countries stop investing billions of dollars in plantations of exotic tree species, and instead learn from the experiences of successful grassroots restoration implemented at scale.

The final article in this issue looks at the key question of how to improve the monitoring of forest landscape restoration in Africa [4.3]. Achieving the ambitious pledges made to date requires the tracking of progress — not just of tree survival and growth, but also of trees' ability to store carbon and provide social, economic and environmental benefits. Systems must be efficient and transparent and incorporate lessons learned from successes and failures. They must document this in a credible and compelling way to encourage donors to invest and help identify the best approaches for scaling up. But this is challenging. Restoration takes years before changes are visible, and objectives vary widely between countries and rely on diverse approaches that affect landscapes in different ways. This requires adaptable frameworks that are tailored to this complexity but can still produce standardized and comparable results. Seven existing tools are presented, alongside an analysis of their strengths and weaknesses; organizations should support and facilitate their implementation for the consistent tracking of progress throughout Africa. Investors and funders also need to include the cost of high-quality monitoring into their proposals. Finally, although it is essential to have solid data, they will be useless unless they can be acted on in the field. This needs to be acknowledged.

Conclusions and recommendations

We are not yet winning the battle against land degradation in the drylands

In most countries, land degradation continues to outpace landscape restoration, meaning that each year more natural resources are lost. Substantially increasing funding to expand conventional approaches to support restoration does not seem to be a realistic option and experiences appear to show that unless well targeted, nor is it likely to be particularly effective. If we want to win the battle against land degradation — in the context of climate change, improving livelihoods and creating economic opportunities, especially for young people — then new approaches must be developed. More attention needs to be given to capitalize on what can be achieved through proven restoration practices, and to mobilize support for comprehensive and effective scaling strategies. This edition of *ETFRN News* contains inspiring examples of restoration successes in African drylands, several of which have already been scaled up. A key lesson is that the challenges of resource degradation can be sustainably addressed only when millions of farmers and pastoralists in each country decide to invest in relatively low-cost restoration actions, which already produce short-term economic and environmental benefits.

We must agree to and adopt effective scaling strategies

This can best be achieved by taking account of the lessons learned and outcomes achieved from the experiences documented in this edition of *ETFRN News* and in related publications. This includes greatly expanded communication that catalyzes grassroot movements, mobilizes rural communities, strengthens the capacity of producer associations, and increases the engagement of donor organizations and governments to support key actors in restoration. Projects that restore even thousands of hectares are important to the people who immediately benefit from them, but they are not enough to reverse the process of land degradation over millions of hectares, and this is urgently required. This can be assisted by increased investment in rural communities, though it is as important to develop and implement forestry and land tenure laws that are appropriate to local contexts. This takes time, however, since policies and legislation need to be approved at various levels. Experience shows that farmers and other rural producers will invest in trees when they perceive that they "own" them, and when rights to manage trees and other resources have been devolved and decentralized resource management has been enabled. Rural communities will be much more likely to invest in water harvesting and other sustainable land management techniques when they have secure land-use rights.

A six-step scaling strategy for regreening has already been developed, based largely on experiences in the Sahel. They do not need to be conducted sequentially, and countries can adapt the actions needed to implement these steps to their own specific socioeconomic and environmental conditions (Reij and Winterbottom 2015).

Step 1. Identify and analyse existing regreening successes.

Step 2. Build a grassroots movement for regreening.

Step 3. Address policy and legal issues and improve enabling conditions for regreening.

Step 4. Develop and implement a communication strategy.

Step 5. Develop or strengthen agroforestry value chains and capitalize on the role of the market in scaling up regreening.

Step 6. Expand research activities to fill gaps in knowledge about regreening.

The framework of these six steps has, for example, been adopted by the Regreening Africa project and has contributed to its emerging successes [4.1].

Shift the focus to simple, low-cost restoration techniques

If the Great Green Wall is to achieve its aim of restoring 100 million ha by 2030, it will need to restore 8.2 million ha every year. This would require an investment of US$36–43 billion (UNCCD 2020) based on an average cost of US$440–530/ha, a level of funding that is unlikely to be mobilized. Scaling up the implementation of restoration techniques can be achieved only if the focus changes to the promotion of proven, locally adapted, relatively simple, low-cost and easily replicable restoration techniques with the best potential for scaling. These include farmer managed and assisted natural regeneration, area exclosures and simple water harvesting techniques such as improved planting pits and contour stone bunds, complemented by tree planting and other restoration techniques where they are likely to succeed. As shown in the articles in this edition, a change in strategic priorities that can significantly help to achieve the many ambitious restoration targets already set — must be adopted by donors and international initiatives.

Natural regeneration will not work in every situation or in every place, such as on soils with a hard crust, even if land was left alone for decades. But where farmers have dug pits and added manure to them, this has led to the re-emergence of agroforestry parklands. Many farmer-led initiatives have succeeded in drylands where population densities are high, with mean annual rainfall of 400–900 mm and on sandy soils. Where population pressure is low, farmers can leave some land fallow to restore its fertility, and firewood is more readily available from natural vegetation, and the consequence is that land degradation continues unabated. But where farmland dominates, with little remaining natural vegetation, farmers have an incentive to increase the number of on-farm trees, as shown in Section 1. A quantum shift to simple, replicable, low-cost and clearly effective restoration techniques, as many cases in this report show, will also help overturn the common belief that when project funding ends, nothing is sustained.

Empower local communities

As is so well stated in an article in this publication, "Restoration is a process, not a single act, and will be successful only if undertaken by local people themselves – massive investments alone cannot succeed" [(vi)]. Regreening landscapes is as much a social enterprise as it is a biophysical and technical one [3.2], and without exception, everyone agrees that local communities must be involved in all aspects of restoration, from initial analysis to planning and implementation. Restoration options should be economically attractive to communities so they invest in them and sustain them; these options must also be underpinned by secure tenure, equitable responsibility and benefit-sharing mechanisms. This in turn has to be supported by government policies and legislation. For instance, current forest laws in most countries do not explicitly recognize rights for smallholders over trees on the land they farm, a constraint that governments can immediately address.

There are examples in most countries of local conventions and bylaws that can be used as a source of inspiration and as models that communities can adapt to their specific circumstances. This demonstrates that when bylaws are inclusively developed and enforced by networks of village groups, they can limit uncontrolled wood-cutting, grazing and bush fires, prevent continued land degradation, reduce conflicts, and increase tree cover [3.1]. But building village and inter-village institutions for rationalizing land use and managing natural resources is more complex than the technical aspects of restoration. Strengthening community-based organizations and increasing the capacity of local government institutions are key pillars to enhancing, sustaining and monitoring the positive impacts of restoration initiatives (Kassa et al. 2017).

Effective documentation and communication is key

This edition of *ETFRN News* illustrates that many countries have already demonstrated restoration successes at a range of scales. One shortcut to achieving progress is to spread the word about these successes and identify men, women and youth to share their experiences. Farmers listen to other farmers who are working in similar environmental and economic conditions more than they listen to experts. And an increased flow of economic benefits associated with the adoption of restoration practices and developing associated enterprises helps to reinforce the behavioural changes needed to sustain and scale up restoration. By capitalizing on many different low-cost forms of communication, thousands or even millions of land users can learn about simple and replicable restoration techniques. Increasing funding for restoration is important, but increasing the rate of progress depends at least as much on enabling the exchange of experience among land managers as it does on the empowerment of local communities and institutions. Unless millions of smallholder farmers and pastoralists

Village in Gourcy province, Burkina Faso that has benefitted from dryland restoration.. Photo: Gray Tappan

decide to invest their scarce resources in restoring the productivity of their land, restoration of African drylands will remain an unrealized ambition – just a dream. For example, it is essential to communicate that investing local labour in FMNR, planting pits, half-moons or contour stone bunds can yield significant benefits from as soon as the first and second year, with increased crop yields and firewood and leaves for fodder or to enrich the soil from thinning and pruning emerging saplings.

Identification and analysis of restoration successes can be achieved quickly — as has been shown in the production of this volume in half a year — to inspire enthusiasm and renew or establish communication among communities, organizations and policy makers. Many people in dryland countries are not aware of successes in land restoration, so it is essential to inform every urban and rural citizen about what has already been achieved in order to foster a "yes we can" attitude, and to counter the common beliefs that nothing is being done and that no progress has been made. Such communication can involve inviting journalists to visit sites of restoration successes and produce stories where land users share their experiences for national and international audiences.

Develop value chains and enterprises

Developing value chains is also crucially important, because it puts more money in the pockets of those who live in the landscape being restored. For women, who often play a key role in the transformation of products, it will help strengthen their economic position. An increased flow of economic benefits — associated with the adoption of restoration practices and the development of associated enterprises — helps to reinforce the behavioural changes needed to sustain and scale up restoration. These economic benefits can be related to the increased production, processing and marketing of non-timber forest products from indigenous trees [2.1], timber [2.2], and sustainable charcoal [(iii), (v)] among others. Much hope is vested in mobilizing private-sector funding for restoration activities. In

Large-scale regreening in Niger. Photo: Robert Winterbottom.

2017, public funding for restoration and conservation was calculated to be US$41 billion per year, four times that of private funding, with an estimated annual shortfall in the global investment required to meet restoration goals in the order of US$300 billion (Ding et al. 2017).

Building viable enterprises is a long and hard road [2.1], but is vitally important for job creation and for providing income opportunities from agricultural and tree-based value chains. It is unlikely, at least in the short term, that private-sector funding will contribute significantly to meeting restoration targets. Governments can, however, facilitate the development of value chains and enterprises by reducing bureaucratic complexity, offering financial incentives and implementing more favourable enabling policies. An increasing number of studies are looking at innovative ways of financing restoration (e.g., Ding et al. 2017; Louman et al. 2019; Shames and Scherr 2020; Zoveda et al. 2020), but we see only theory and rhetoric at the moment. As with much talk about carbon credits, REDD+ and similar initiatives, the hopes raised by these were not realized on the ground. And once again, there are no immediate signs that any significant amount of private-sector financing and investment is going to materialize in the immediate future.

Improve monitoring of land restoration

Neither AFR100 nor the Bonn Challenge can at this moment show significant progress toward meeting its restoration targets. In 2016, the Restoration Barometer was developed to help pledgers identify, assess and track action on their restoration commitments. But to date, data is available for only five countries (Dave et al. 2019). Regarding the Great Green Wall, details from all 11 countries have been published (UNCCD 2020), but there are discrepancies between the figures and impacts reported, and those on the website of the Pan-African Agency for the Great Green Wall. And while monitoring the number of trees and hectares is a challenge, measuring the impacts of restoration on social,

economic and environmental indicators appears to be an impossibility, at least for now. Fortunately, much progress has been made with remote sensing technologies and other means for assessing, mapping and reporting on changes in land use and land cover. Interest is also increasing in collaborating on data-sharing platforms to facilitate real-time tracking of restoration and outcomes, such as the global restoration monitor being developed by the Global EverGreening Alliance. These technologies can help to identify additional restoration successes and can significantly improve the monitoring and impact assessment of activities aimed at scaling up restoration.

Projects that invest tens of millions of dollars of public money have to justify such huge expenditures to the global taxpayers who are ultimately supporting them. This could be addressed in part by the development of a "barometer" similar to the Restoration Barometer that quantifies and transparently reports the amounts of funding pledged by donors, governments and organizations, and the amounts that are actually dispersed to implementing restoration activities.

Linking restoration with carbon sequestration

Commonly, people think of sequestered carbon as what is fixed in trees, in wood, and in above-ground biomass. This means that drylands and dry forest get limited attention. But what is shown in some of these articles is that restoring drylands may have perhaps the largest potential for sequestering carbon in the world, but in the soil (FAO 2017), rather than in the trees themselves, as much of the carbon in the wood will be returned to the atmosphere when it is burned as firewood or charcoal. Many articles in this volume made the important link between dryland restoration and soil carbon sequestration (e.g., [1.6], [2.6], [3.4], [3.5]). Soil organic carbon, fundamental to plant growth, is much lower in dryland soils than in soils in more humid or temperature regions, and has been further reduced by land degradation. But research shows that improving tree cover and rehabilitating farmland and rangeland can massively increase soil carbon stocks. And if these stocks are measured and incorporated into calculations of nationally determined contributions (NDCs) to meet pledges to the Paris Agreement, this could leverage much more funding for dryland restoration.

Develop research to fill gaps in knowledge

There is an urgent need for additional robust data on restoration costs, and on the benefits to crop yields and food security, wood and fodder stocks, income diversification and poverty reduction, household resilience, carbon sequestration, water supplies and groundwater flows. More attention needs to be devoted to an analysis of aggregate and broader impacts of restoration on people, with less focus on counting trees and hectares.

Some researchers recently stated that quantitative evidence for bold claims about FMNR is built mainly on experience in Niger, and they recommended further research (Chomba et al. 2020). However, field observations in various countries show that smallholder farmers in and outside the Sahel and the Greater Horn of Africa are keen to invest in FMNR [4.1]. Another study assessed how human impact, land degradation and limitations on seed dispersal affected regeneration across 316 plots in agroforestry parklands (Lohbeck et al. 2020). They concluded that the presence of desired species is a precondition for successful FMNR and that regeneration needs to be protected from grazing, but the study was limited to two similar areas on either side of the Ghana-Burkina Faso border.

Articles in this edition clearly contradict these two papers. Also, many people do not realize that the scale of FMNR in Niger was first observed between 2004 and 2009 (Reij et al. 2009) and began to be

promoted more widely from about 2005. Though the massive increase in trees cover in parts of the Sahel that is now evident had already begun at least 10–15 years before this, since the 1980s. This is seen in findings based on the analysis of high-resolution satellite images in combination with field visits, many of which are presented for the first time in this publication. The growing interest of agroforestry researchers in FMNR is to be applauded and will generate more hard data about multiple impacts, but this must be conducted over much larger scales and time frames than the two examples discussed in the previous paragraph.

Complexity constrains implementation

Every donor agency and environmental think tank now emphasizes the need for a landscape approach or integrated landscape management (e.g., Shames and Scherr 2020; UNCCD 2020). But the experiences documented here show that the landscape approach did not play a role in most cases. In Niger, transformation was achieved on 5 million hectares because of decisions made by individual farmers to invest in on-farm trees, with no landscape planning [1.9]. This was also the case on Mali's Seno plain [1.5] and in Senegal's peanut basin [1.1]. The only example where a form of land-use planning played a role was in Tigray, Ethiopia [1.3], in an area characterized by steep slopes that made it necessary to terrace or revegetate slopes before undertaking restoration activities in the valleys below. Adopting a landscape management approach from the start tends to involve "outsiders" and increases the complexity of projects, which slows implementation [4.2]. This may also lead to disconnected initiatives with varying goals, such as conservation or economic, or even increase conflicts between people or groups in different parts of the landscapes concerned. To achieve ambitious restoration targets, it helps to start simple, and to gradually build complexity based on emerging needs and opportunities.

A call for action

Now is the time to build on the impressive set of restoration successes documented in this issue, and to make full use of the lessons learned from these very encouraging experiences. Locally managed restoration must be promoted as a matter of urgency, supported by local institutions, organizations and governments, with public funding. Private funding may follow, but is far from guaranteed, especially since the inherently low levels of productivity in drylands are much less likely to yield the rate of return that investors could obtain elsewhere. Farmer managed and assisted natural regeneration, area exclosures and simple water harvesting and soil conservation techniques have been highly successful and at a low cost. Much can be achieved by mobilizing rural communities and catalyzing grassroots movements led by restoration champions.

And in all cases, to effectively support restoration programmes and projects, all it is vital that those involved must do their utmost to guarantee that these basic tenets are adhered to.

- **Ensure full participation** of all land users, build on their knowledge and strengthen their capacities.
- **Support communities** to realise clear economic benefits, especially for women and youth.
- **Enable local institutions** to develop and enforce their own inclusive conventions and bylaws.
- **Engage governments** to elaborate policies and legislation that stimulate investment in trees.

Large-scale regreening is possible, at scale and at low costs, as has occurred for example in Niger over millions of hectares. But monitoring the impacts also needs to be much improved. Photo: Robert Winterbottom.

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Farmer and community-managed restoration

Photo, previous page: An area of farmer managed natural regeneration near Kongoussi, central Burkina Faso.
Photo: Gray Tappan

Restoration of agricultural landscapes and dry forests in Senegal

Gray Tappan, Mike McGahuey & Robert Winterbottom

A Senegalese farmer explaining the benefits from protecting and managing *Faidherbia albida* trees in his field. Photo: Robert Winterbottom

"Decentralized, community-led initiatives lead to positive and sustainable outcomes — massive investments are not needed."

Introduction

Senegal — like all the countries of the Sahel — presents a vivid picture of changing landscapes that reveal the interdependence and interactions between the country's people and the land that sustains them. A five-fold growth in the population since 1960 has driven a dramatic loss of savanna, woodlands and forests. This can be seen in the extent and complexity of changes in land use and land cover (LULC) through aerial and satellite photography from the 1950s and 1960s, and studies integrating time-series imagery with ground-based monitoring (Tappan et al. 2004; CILSS 2016).

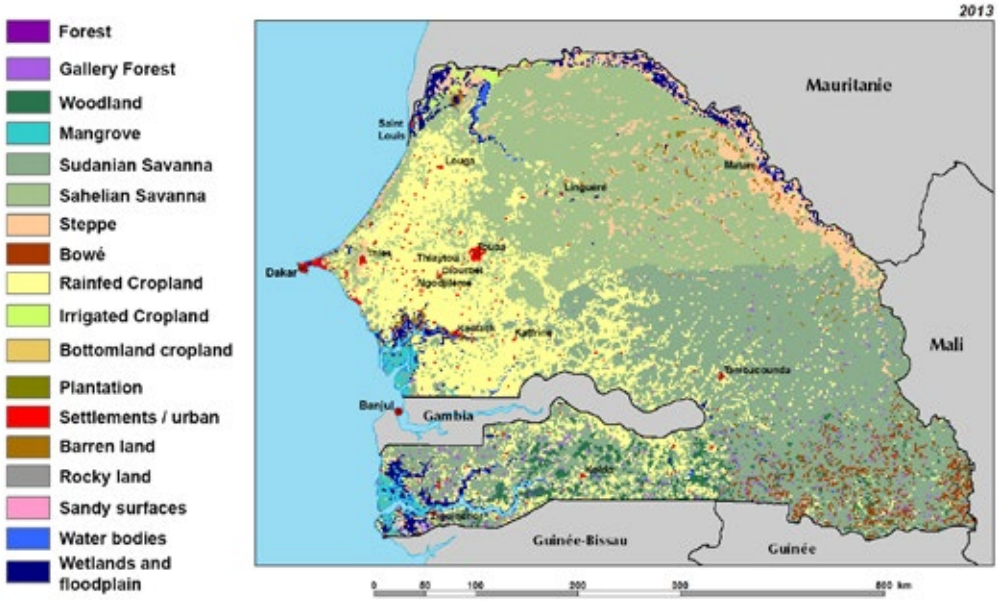
Senegal is known for its landscape diversity, from the semi-arid open savannas and steppes in the north, typical of the Sahel, to

Gray Tappan, Geographer, United States Geological Survey, Sioux Falls, South Dakota, USA; **Mike McGahuey**, Fellow, Global Evergreening Alliance, Arlington, Virginia, USA and **Robert Winterbottom**, Fellow, Global EverGreening Alliance, Stoddard, New Hampshire, USA

wooded savannas, woodlands, forests and wetlands in the southern Sudanian and Sudano-Guinean zones. Superimposed on this are agricultural regions, including the large "Peanut Basin," where high population density and farming activities have completely replaced the original wooded savannas.

The most striking change over the past decades has been the expansion of cropland into central and southern Senegal (Tappan et al. 2004). In a recent mapping exercise (CILSS 2016), trends in LULC classes using 40 years of Landsat imagery showed that cropland expanded by 26% between 1975 and 2013, including into protected areas and on plateaus and terraces with soils once considered too marginal for growing crops (Figure 1). The expansion has also resulted in the fragmentation of savannas and woodlands, replacing contiguous expanses of natural habitat with a mosaic of crop fields and woodlands. During the same 38-year period, woodlands decreased by 42%, due to cropland expansion and to uncontrolled timber and charcoal extraction, livestock grazing and frequent bush fires. The decrease was also influenced by misguided agricultural development policies, weaknesses in implementing decentralization policies, and outdated forestry practices (Faye and Ribot 2017).

Figure 1. Land use and land cover in Senegal, 2013. Based on visual analysis of Landsat images and extensive field observations. Source: Tappan et al. (2016).



But despite these changes in land cover, important and sustained local initiatives have protected the remaining forests, assisted natural regeneration on agricultural fields, controlled bush fires, and promoted the sustainable harvesting of natural products. These efforts have helped to restore landscapes while improving farmers' livelihoods and strengthening their resiliency. Scaling up of such practices requires an understanding of the key enabling factors and critical interventions.

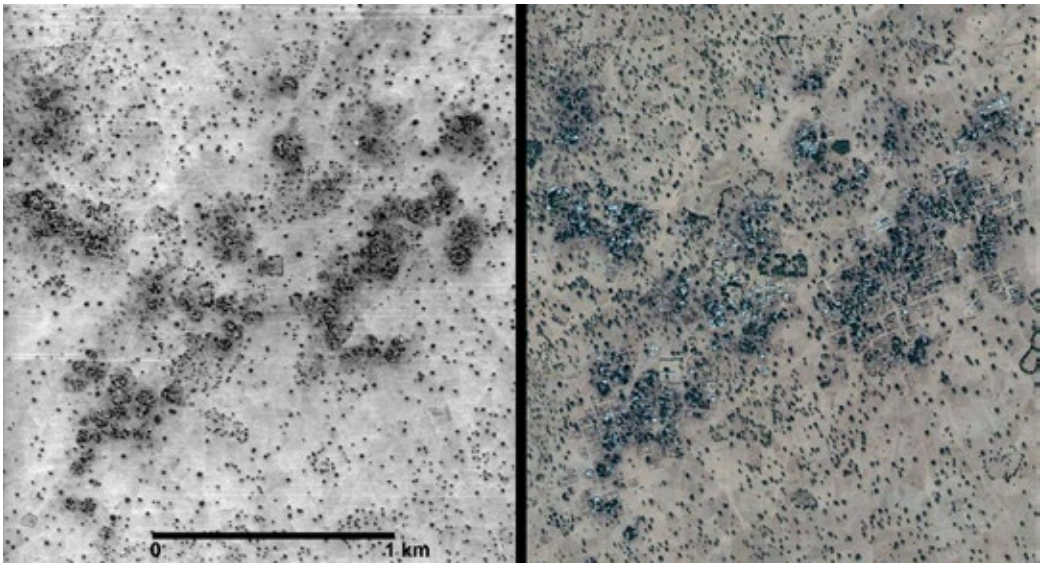
Aerial view of *Faidherbia albida* among rainfed cropland at the end of the rainy season, with their white, leafless canopies. Photo: Gray Tappan

Regeneration of agroforestry parklands

The Peanut Basin of west-central Senegal is centred on former Wolof kingdoms, with enclaves of Serer communities. It was named after the introduction of peanut crops by the French in the early 1900s and is the most fundamentally altered region in the country (Tappan et al. 2004). By the 1980s, the pressure on land led to a major decline in the use of fallows, grazing land decreased to a minimum, and continuous cultivation replaced nearly all natural vegetation, which once comprised parklands dominated by *Acacia raddiana* in the north and *Faidherbia albida* elsewhere.

Despite the high rural population density and resource degradation, local farming systems have protected natural resources and generated substantial improvements to the land. These include increases in tree cover in cropland and grazing areas that resemble the integrated agro-silvopastoral systems that were found in the region 50 years ago. A participatory study of two farming communities near Bambey used remote sensing to provide high-resolution time-series images to map land use and land cover (Tschakert and Tappan 2004). Ngodjilème a Serer village, and Thiaytou a Wolof village, were selected for more detailed assessments. In both communities, rainfed agriculture is an important source of income, primarily from the cultivation of millet, peanut, sorghum and cowpea (Tschakert and Tappan 2004).

In both villages, farmers engage in the protection of mature trees in the fields; these were dominated by *Faidherbia albida* in association with several other species (Stancioff et al. 1986). This species has many ecological and economic advantages: trees lose their leaves in the rainy season and fix nitrogen, providing Sahelian farming systems with a major source of nutrients (Charreau 1974); and they

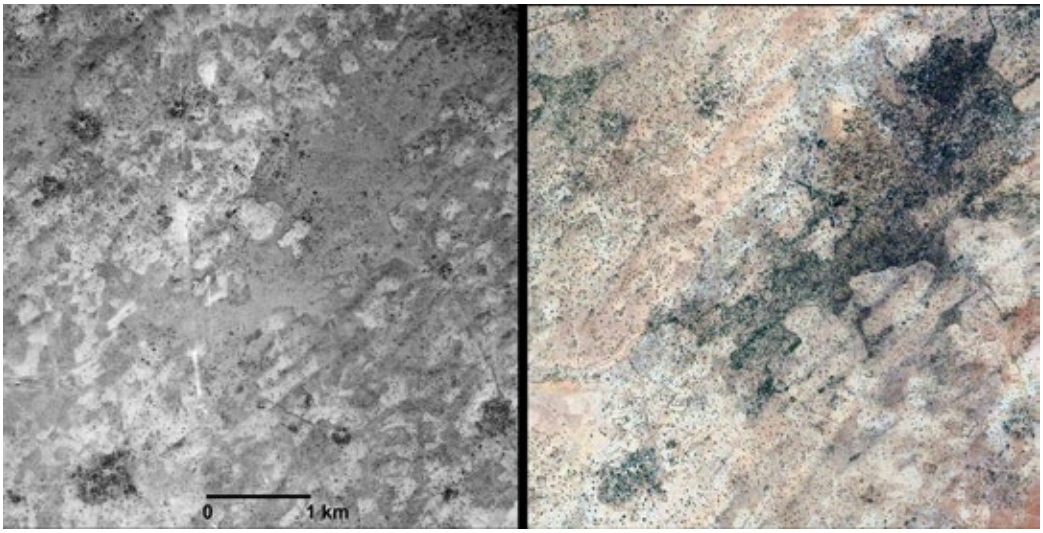


Comparison of the Serer village of Ngodjilème and surrounding cropland based on the same field of view in March 1989 (left) and February 2019 (right). Sources: JICA, and Maxar Technologies with Google Earth.

act as windbreaks in the dry season. Economically, this land-use system can increase millet yields by 30 to 50% or more, while providing an important source of fuelwood, poles and fodder (Felker 1976).

Time-series remote-sensing imagery assessed changes in land resources and farming systems. The study used aerial photography from March 1989 and satellite imagery from February 2019 for Ngodjilème and from March 2020 for Thiaytou. Although the 1989 photograph was film-based, the image resolution from both sources is similar, at approximately 2 metres, facilitating direct comparison.

Ngodjilème is a typical Serer village, with dispersed groups of homesteads separated by fields of farmed parklands. Driven by rapid population growth, it has expanded 240% in 30 years. In the images above, trees are seen as dark spots. Overall field tree density was at a low point in 1989, having decreased slightly relative to a 1968 satellite photograph which showed an average cover of 4.3% (Tschakert and Tappan 2004), following severe droughts in the 1970s and 1980s (Lericollais 1987). After 1989 tree cover and density almost doubled — from 4.1% in 1989 to 7.7% in 2019 — and this increase was not limited to fields immediately around the village. To document changes in land resources, Tappan et al. (2000) took time-series landscape photographs at dozens of ground sites in the Peanut Basin. The photographs showed that while some mortality occurred following the 1982-84 drought, tree cover among mature trees remained relatively stable into the late 1990s. They also observed that natural regeneration of field trees was very low during the drought years but increased in the wetter years that followed. While better rainfall contributed to the regeneration of trees, the ultimate fate of small regenerating trees and the increase in tree cover had more to do with active protection by farmers. This is consistent with the indigenous and adaptive intensification that Serer farmers adopted decades ago to fight the degradation of land and resources. The practice includes the integration of agriculture, tree protection and regeneration, and animal husbandry (Garin et al. 1990; Lericollais and Faye 1994; Tschakert and Tappan 2004).



Comparison of cropland and communal grazing land around Thiaytou village (bottom left of photo) in March 1989 (left) and March 2020 (right); vegetation in the commons improving from degraded open shrub savanna to dense wooded savanna. Sources: JICA, and Maxar Technologies with Google Earth.

A similar increase was observed around the Wolof village of Thiaytou over approximately the same period. The photograph from March 2020 (right) shows the integration of livestock, with a well-maintained livestock corridor providing access from the village to grazing land in the northeast. It is clear that the village has not grown much in size over 31 years; this is due to substantial rural-to-urban youth migration. Important differences shown in the two images include the almost total loss of short-term fallow and the doubling in tree cover from 1.9% in 1989 to 4.0% in 2020, indicating that farmers have given considerable importance to the protection and management of field trees, particularly *Faidherbia albida*. But the most striking change is local protection and tree regeneration in community grazing lands (centre and upper right of the 2020 photo). This area has been transformed from degraded open shrub savanna to a dense wooded savanna with 61% woody cover, equivalent to the woodlands of Senegal's southern regions.

Managing agroforest parklands and the results from protecting trees on cropland can be seen in hundreds of other villages throughout the Peanut Basin and beyond. The historical record of high-resolution satellite photography from 1968, aerial photography from the 1970s to the 1990s, and the excellent detailed satellite record in the last two decades clearly show the progress being made by local people in improving and diversifying the resource base. The villages of Ngodjilème and Thiaytou are just two examples of successes in managing agroforestry parklands and the results from protecting trees on cropland.

Successful community-based forest restoration in Sambandé

Around 2000, the 1,050-hectare Sambandé forest in Kaolack Region was being degraded by recurring brush fires, illegal fuelwood cutting, agricultural encroachment, and excessive pruning by migrating herders. The 1996 Decentralization Law gave authority to manage the forest to the local Keur Baka

commune, but the commune members lacked the financial resources and institutions to develop and implement an effective management plan (M.L. Bodian, pers. comm., 2020). But since then and as a result of two GTZ (German Agency for Technical Cooperation)-led projects, the development and implementation of sustained-yield management plans have restored much of the forest. By 2020, the forest had become well-wooded and productive. New revenue streams from the sale of charcoal, firewood and tree fruits improved the well-being and resilience of surrounding populations and paid for Sambandé's management.

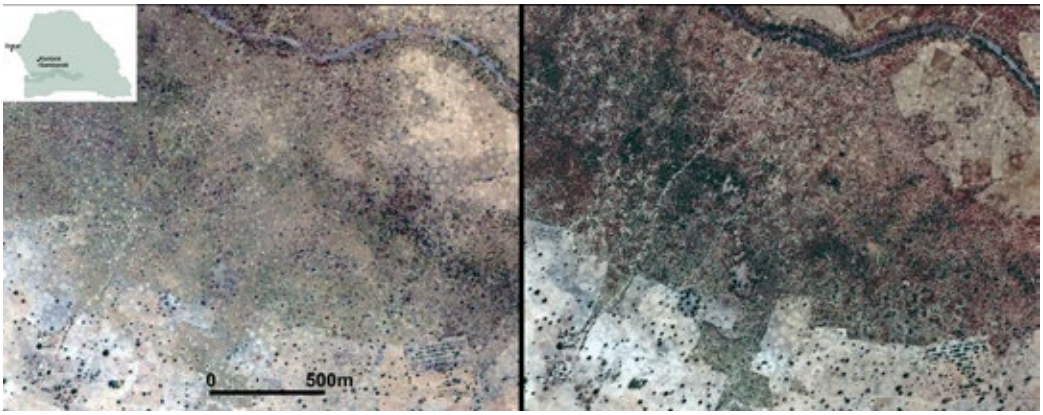
What made the difference? Most importantly, the people in the surrounding area treated the Sambandé forest as their property, managed it responsibly and considered it their savings bank. For risk-averse farmers, this change in attitude required evidence that community-based forest management was viable for both the community and the forest. The process was initiated in 1999 when one of the GTZ projects helped the surrounding villages to develop and negotiate a local convention that provided a framework of regulations and allowed management rights to be transferred from communes to villages (M.L. Bodian, pers. comm., 2020).

Within this framework, projects helped communities establish a simple, protected area management plan aimed at restoring the degraded forest and supported by an inter-village platform called the *cadre d'animation et de concertation* (Robinson 2011). The initial plan limited forest use to residents of the nine surrounding villages, prohibiting the cutting of green wood but allowing the gathering of deadfall (for domestic use only), and allowing tree fruit to be sold. Residents who violated the rules or outsiders who gathered any forest products would be fined, and the village group organized guards to patrol the forest and escort violators to village authorities.

Within a couple of years, villagers saw that the forest protection plan they themselves had adopted and enforced produced evidence that the approach was working; areas once bare were now covered with trees, some several metres tall. The Decentralization Law was beginning to work for the community. As stated by Robinson (2011 p. 39) about the implementation of protected area plans in the Kaolack region, "For the first time, villagers asserted that they 'owned' uncultivated land and prosecuted residents of other villages who used the trees occurring there."

Through a further (GTZ) project, in partnership with a national programme and the Sambandé community, a forest management plan was prepared, technically validated by the Senegal Forest Service and approved by local government. The plan, which is still operational today, was oriented to revenue generation and sustainable yield and included the commercialization of charcoal and firewood as well as tree fruit. In addition to providing technical assistance, the project strengthened local institutions to manage the forest, and helped transform the original platform into an Inter-Village Committee.

The relationship between the Sambandé community and Forest Service staff changed, from one of suspicion and adversity to a true partnership. Over time, both the Forest Service and local communities found that collaboration was more effective in achieving their respective objectives. Some foresters deviated from procedures in positive ways that provided support and legitimacy to local regulatory authorities, and Forest Service administrators admitted candidly that while community regulators rarely followed procedures, they were more effective than forest service agents alone (Robinson 2011; 2018). Sambandé provided proof of how communities and the State can collaborate to restore natural forests and improve rural livelihoods.



Time-series images of Sambandé forest (2003 left; 2020 right), revealing the impacts of the sustained-yield management plan developed and implemented by local community-based organisations. Sources: Maxar Technologies with Google Earth.

The Sambandé outcomes strongly affirm a foundational premise of the Decentralized Law of 1996 and the Forest Code reforms of 1998: when people feel secure about their ownership of something of value, they will care for it and invest in it. The evidence also affirms that when rural populations invest in the care of a forest, Forest Service agents can spend less time policing and more time using their forest management skills to assist rural populations in managing their forests, thereby ensuring forest sustainability.

By paying their taxes, investing local resources in managing the forest and improving the livelihoods and general welfare of local people, villagers around Sambandé proved their autonomy, particularly in the past 5 years when they operated without project support. Sambandé's experiences point the way to supporting sustainable, community-managed forests.

Conclusions

In the above initiatives, self-motivated populations increased food security and reduced vulnerabilities to climatic shocks by restoring and sustainably managing local forest resources. To regenerate agroforestry parklands, farmers built on traditional systems to increase on-farm tree density and convert degraded lands to densely wooded savannas. These actions increased crop yields and produced new sources of livestock browse. The population of Sambandé restored the local forest and managed it to sustainably produce fuel and fruit. The agroforestry parklands were restored without a project. Modest project support helped the Sambandé community to establish local institutions that set and enforced rules that applied sound forest management practices and strengthened targeted value chains. Project assistance was phased out when the community's capacity was sufficiently strong to manage the forest sustainably.

The sustained achievements from the locally managed initiatives described above lie in stark contrast to the poor track record of longer-term impacts from many large, centrally controlled projects that focus more on infrastructure than on capacity building. While the Sambandé projects built the community's capacity to exercise choices when managing forest resources and enterprises, centrally

controlled projects often make critical decisions in the place of the ultimate beneficiaries, weakening the sense of local ownership and increasing the chance that forest management will not continue after the end of project.

The time and effort needed to scale up these successes have been much reduced by taking stock of what has worked. This includes identifying the changes that led to success, such as the transfer of rights and responsibilities, use of appropriate technologies, greater roles for local populations in developing forest value chains, and identifying the steps that established those changes, e.g., training, peer-to-peer visits, and policy modifications.

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Post-project impacts of restoring degraded land in Tahoua, Niger

Abdou Hassane & Chris Reij

Restored farmland close to Batodi village in 2018. Photo: Chris Reij.

"Individual smallholders continue to use simple and replicable restoration techniques many years after a project promoting these techniques ended."

Introduction

From 1988 to 1995, a soil and water conservation project was implemented in Niger's Tahoua Region, specifically in Illela District, funded by the International Fund for Agricultural Development (IFAD). The project used water harvesting to restore degraded land, promoting simple and easily replicable techniques such as *zaï* planting pits (*tassa* in the local Hausa language) and half-moon catchments.

This was a remarkable approach, because at the same time, two major projects were relying largely on heavy machinery to restore degraded land: the German-funded Rural Development Project in Tahoua District, and a high-profile, Italian-funded and FAO-implemented project in Keita District. Both of those projects used tractors, bulldozers and graders to build bunds (embankments)

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Planting pits and half-moons: restoring degraded land and increasing crop yields

Water harvesting is a term that describes a range of methods used to collect and concentrate rainfall and runoff. This increases the amount of water available to plants and therefore improves plant production in arid and semi-arid areas (Reij et al. 1988). Planting pits and half-moons are simple constructions that act as micro-catchments; they gather the runoff from uncultivated parts of the land in small areas where crops are sown. The amount of additional water that is collected and made available depends on the ratio between the size of the uncultivated catchment area and the size of the pit or half-moon. In Niger, millet is the dominant crop grown in such pits and half-moons, but some farmers cultivate a mixture of millet and sorghum.

Planting pits. Photo: Abdou Hassane

Planting pits were introduced in Illela District in 1989 and have since been widely adopted. They usually have a diameter of 15 to 20 cm and a depth of 10 to 15 cm. The spacing between the pits varies, but they are generally less than one metre apart. Often dug about 0.8 metres apart, there are thus usually around 16,000 pits per hectare. Digging pits in soils with a hard surface, which are common in this area, is heavy work, and requires an investment of labour ranging from 40 to 120 person-days per hectare, depending on the hardness of the soil crust and the physical strength of the labour force. Since pits are generally dug during the dry season, when there is less demand for agricultural activities, the work can be done gradually over several weeks or months by family labour, or in less time by hired labourers or traditional work parties.

Half-moons are much larger than planting pits. Constructed in staggered rows, each is made of raised bunds of soil (with stones if available) in an arc that concentrate runoff, Originally, spacings between the centres were 6-8 m, with 4 m between rows (325-425/ha). After the project ended, farmers made them smaller and closer so the tips of the arcs touched each other, further increasing the number per hectare.

A millet crop in half-moons. Photo: Chris Reij

Farmers always add some organic matter to each pit or half-moon. This can be manure, compost, kitchen waste, foliage from trees and shrubs, or crop residues. Such organic matter tends to be scarce, and because it is concentrated where crops are sown, it thus also increases soil fertility exactly where it is needed by the growing plants.

Crop growing under *Piliostigma reticulatum*. Chris Reij

with upward sloping wings on degraded plateaus and to plough the land between the bunds. They did so across entire plateaus to reduce runoff into the valleys and reduce erosion and damage from flooding downstream. The local population was mobilized with food for work to cover the earthen bunds with stones to make them stronger, with the aim of reduced maintenance needs.

The IFAD-funded project took a different approach, providing hand tools to villagers so they could dig *zaï* planting pits and half-moons, an idea that emerged during a study visit by 13 farmers (10 men and 3 women) from Illela to the Yatenga Region in Burkina Faso. There, they visited Yacouba Sawadogo, an innovative farmer who improved traditional *zaï* planting pits by making them deeper and wider. The IFAD project replaced food for work with another incentive with longer-term benefits: community infrastructure for work. If villagers made good progress digging *zaï* pits and half-moons to restore land, the village would receive financial support for building a new school classroom, health clinic, or well.

Incredible impacts

Amount of land restored

A total of 5,765 hectares of severely degraded land, plus 585 hectares of silvopastoral land were restored in the district to productive land over the eight years of the project. These figures are considered to underestimate the project's achievements, as they do not take into account the fact that the simple water harvesting techniques, in particular the planting pits, were also rapidly adopted by farmers from villages outside the project area, who saw their positive impacts. For instance, farmers in the adjacent Keita and Tahoua districts — where the two projects that focused on mechanical intervention were implemented — also began digging pits between the bunds constructed using machinery. The data on areas restored also do not include the spread of these techniques after the project ended.

Left: A typically barren plateau in 1984; Right: A restored agroforestry landscape in the Badaguichiri valley in 2006. Photo: Chris Reij

Increased crop yields

Between 1991 and 1996, the impact on cereal yields was measured for both planting pits and half-moons, many taken on the same fields. Rainfall for Badaguichiri, a small town in Illela where the project headquarters was based, ranged from 369 mm in 1993 to 726 mm in 1991. The average yields of millet and sorghum during the six years that impacts were measured were 513 kg/ha for the planting pits and 535 kg/ha for the half-moons, with yields ranging from 300 kg/ha in 1993 (with low and unevenly distributed rainfall) to almost 1,000 kg/ha in 1994 (a year of good rainfall). These yields may seem low, but they were four times higher than the average yields in control plots without interventions. When some mineral fertilizer was added yields increased to almost 1,500 kg/ha. The clear and significant difference between crop yields on restored and unrestored land made farmers inside and outside the project area quickly adopt the water harvesting techniques.

Land purchase

After witnessing the impact of these land restoration techniques, villagers began buying severely degraded lands to bring them back into production by digging planting pits and constructing half-moons. Between 1988 and 2006 land values certainly increased, and some people sold the restored plots for a higher price. The emergence of this new land market for restored cropland was significant. In 1998, 40% of household heads interviewed said that they had bought degraded land to restore it in this way (Hassane et al. 2000). Men, and also women, were also selling fields with sandy soils to generate cash with which they could buy barren degraded land that could potentially be restored with water harvesting techniques. The costs of such plots varied, from CFA 50–60,000 (US$100–120) per hectare where degraded land was still available, to up to five times higher (around US$600) where such land was scarce. Abdoulaye and Ibro (2006) found that the average price paid for plots

Close to Batodi village, this degraded plateau in 1990 was restored using planting pits and stone bunds. Photo: Chris Reij.

of degraded land was CFA 80,400 (US$160) per hectare, with the average price for degraded land restored with planting pits being CFA 145,500 (US$290).

Food security

The restoration of severely degraded land also led to an increase in household food security. It was estimated that in a drought year, a family without restored land produced only 42% of its cereal requirements, but a family with some of its cropland restored produced 72%. In a year of good rainfall, a family without restored land just achieved food security, but a family with restored land produced a surplus of 70%.

Income from labour

Restoring degraded land with planting pits or half-moons requires a significant investment of labour, and building these constructions soon became an income-earning opportunity. Some farmers specialized in the techniques, and were hired by fellow farmers at a cost (in the 1990s) of about one US dollar for a half-day of work. Some families used their own labour, but 76% of farmers interviewed had hired labourers, and 37% had also organized traditional work groups (Hassane et al. 2000), with an indication that this also led to a strengthening of these traditional work parties (*gaya*), which had been declining.

What happened post-project?

More trees, more fodder

Field visits between 2004 and 2019 showed that many farmers continued to maintain and even expand the use of these water harvesting techniques. This was in stark contrast to what happened in

A new vegetable garden on restored land in Adouna, 2006. Photo: Chris Reij

the adjacent districts, where soil and water conservation projects relied on the use of heavy machinery and externally financed interventions. The land restoration techniques used by those projects were not maintained or continued by local communities or the government.

By the end of the IFAD project, in 1995, large additional areas of degraded land in Illéla District along the main road to the regional capital of Tahoua had been restored by individual farmers. At that time, the plateaus were still largely devoid of trees and shrubs, with an almost uninterrupted view of treeless landscapes for kilometres. But today, parts of these same plateaus have many trees, quite dense in places. The reason is simple. Farmers use manure in the planting pits, and the manure contains the seeds of woody species that have been browsed by livestock. If these seeds germinate and farmers decide to maintain the woody species that grow from them, a new agroforestry parkland emerges. This is exactly what happened in this area, which is now much greener than it was 25 years ago.

In 2019, in the village of Batodi, sedentary pastoralists mentioned that all their livestock now stay in or around the village throughout the entire year. Previously, part of their herds would spend the dry season in Nigeria. According to the pastoralists, it is now possible to keep all their livestock near the village year-round because of the increased number of trees in the surrounding landscape, which produce sufficient fodder for their needs. It is not yet clear whether similar situations exist in other villages, but if more herds stay in Niger rather than migrating to Nigeria during the dry season, it may also help reduce the risks of conflicts in Nigeria between herders and farmers.

More water, more vegetables

In Batodi, situated on what was a barren plateau, farmers began to restore degraded land at the end of the 1980s. Villagers then observed a significant rise in water levels in their wells. When villagers were

A vegetable garden with *Moringa oleifera* trees in the village of Batodi in 2018. Photo: Chris Reij

asked how they explained the increase, their unanimous answer was "Allah." However, during further discussions, they acknowledged that before they restored the land with planting pits and half-moons, any rainfall quickly disappeared as runoff. After they restored the land, they noticed that much of the rainfall now stayed on the land, and they understood that this led to increased infiltration and groundwater recharge.

By 2004, villagers estimated that water levels had increased by around 14 metres, to just two to four metres below the surface. This allowed them to create four vegetable gardens around several wells, increasing to ten gardens in 2012, and eleven by January 2019. This meant that villagers could start producing onions, cabbage, lettuce and other vegetables on land that used to be barren and degraded. Field visits in 2018 and 2019 also showed a shift toward growing moringa trees (*Moringa oleifera*), which has edible leaves, flowers and pods, all with high nutritional value. The main problem facing the new gardeners is getting access to good quality seeds. There is no problem with the marketing of their produce, as it is in high demand, with people from surrounding villages coming to buy the surplus production not consumed by the farming families themselves.

After the project ended, farmers quickly began to reduce the spacing between the half-moons and between the rows of half-moons. Many of them perceived the uncultivated parts of their land not as a source of runoff, but as space that could be cultivated. This is not surprising in areas with high population pressure on the land. Practice also shows that in Illéla District, farmers gradually shifted from using half-moons to planting pits, because they feel that the latter technique is simpler and also more effective in restoring degraded land.

Conclusions

When the IFAD-funded project started in 1988, few people could have imagined that 15 years later the degraded plateaus would be covered with trees on land restored to production by individual smallholder farmers. And no one imagined that a village on a barren degraded plateau would one day produce enough vegetables to meet its own needs and produce a surplus for sale, because water levels in the wells had risen so much. Furthermore, it was inconceivable at that time that restoring degraded land would lead to the emergence of a land market, with people buying degraded plots of land with the aim of restoring them.

Field visits between 2004 and 2019 showed that individual smallholder farmers have continued to use these introduced and adapted water harvesting techniques. Smallholder farmers who restored degraded land then developed new and resilient agroforestry systems and increased food production. By doing so they have increased their resilience to climate change and many are now much better off than they were 30 years ago.

However, there is still a need and scope for further improvements. First, farmers would benefit from better access to good-quality seeds and to fertilizers. Second, the new agroforestry systems could have denser tree cover and contain a more diverse range of tree species. And third, improved rural roads would facilitate access to markets, which is important for villagers who are now producing surplus vegetables during the dry season.

The restoration of degraded land in Illéla District has transformed barren plateaus into productive land. This is due to the insights and efforts of many individual farmers who decided that it was in their best interest to invest in these restoration techniques. There is now a great opportunity for follow-up interventions to further support the development of smallholder agriculture, and to replicate this positive experience in other regions and countries.

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Successful landscape restoration in Abreha We Atsbeha watershed, Tigray, Ethiopia

Mitiku Haile & Dawit Gebregziabher

The landscape in Naeder Adet District, showing terraces that support land restoration.
Photo: Dawit Gebregziabher

A village is globally recognized for becoming nutritionally self-sufficient through land restoration."

Introduction

The village of Abreha We Atsbeha in eastern Tigray is in one of the most degraded areas in the region. The short rainy season of two to three months, coupled with an increasing population, further aggravates the challenges facing the inhabitants. Water scarcity and the erosion of fertile soil have accelerated land degradation and contributed to declining agricultural productivity, meaning that the local community has been food insecure for many years. Due to this, in 1998 villagers were given two choices by the government: either be resettled to an area with more conducive climatic conditions, or implement landscape restoration with the help of the Ministry of Agriculture. The local community found it difficult to accept relocation. The only alternative was to join hands and reverse land degradation.

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It was not easy to reach an agreement among the local community members at first, although most family farmers chose to participate. With the help of strong village leadership and an ability to communicate openly, honestly and transparently, people started to invest in restoration. Aba Hawi, the village leader of Abreha We Atsbeha, once commented on the procedures used to introduce and disseminate technology. "First, the leader must be a model farmer and take the initiative to test techniques and crops, to demonstrate to other farmers that they work. This is because it is difficult to change others without changing the attitude of the leader." The major contribution he made to his community was to change their attitudes to accepting the restoration of degraded lands as the best option to become self-sufficient in food.

Many hands make light work

Restoring degraded land is one of the policy pillars of the Ethiopian government in general, and of the regional government of Tigray in particular. Decentralisation policies also enabled the community to be actively involved, and to develop ownership of and a passion in the rehabilitation process. This has greatly contributed to the successes in this watershed. The vast majority of the labour required was contributed by the community. Some organizations contributed both technical and financial support, in some cases since the start of the programme, but the local community always took the lead. Involved organizations included the German development cooperation (GIZ), the World Food Programme, the World Bank, Mekelle University, Tigray Bureau of Agriculture and Rural Development, Relief Society of Tigray and the Ministry of Agriculture. During this initiative local bylaws were also developed to guarantee equitable benefit sharing for every group in the community.

The combined efforts of the community and other organizations in this landscape restoration process have greatly contributed to its many positive impacts. One of the indicators of success is the increased production of crops for sale, using irrigation water from new hand-dug wells, one of which has the capacity to yield an average of 14,795 m^3 of water per year (Tadesse et al. 2016). This has enabled the local community to produce two or three crops per year (Biedemariam et al. 2017), including cereals such as wheat, maize and barley; vegetables such as cabbage, tomato, pepper and onion; and fruits such as avocado, mango, guava, orange and lemon (Negusse et al. 2013).

What was achieved?

The total area of the Abreha We Atsbeha watershed is 6,766 hectares (ha), of which 4,644 ha (69%) was restored using exclosures (see box), including 1,500 ha of afforestation or reforestation, and the rest using assisted natural regeneration supplemented with soil and water conservation (Haileselassie 2013). Another 899 ha is cultivated land. Crucially, following the construction of 55 check dams in the watershed and associated regreening, the increase in groundwater has allowed the irrigable portion of this cultivated area to increase to 450 hectares (Haileselassie 2013).

This integrated landscape restoration process yielded a number of benefits. These included improved soil quality, groundwater recharge and reduced soil erosion. As these benefits were apparent, this increased the motivation of the local community to further engage in restoration. In addition, the soil type in this watershed is mainly highly permeable sandy soil, and this has greatly contributed to increasing groundwater recharge (Gebregziabher et al. 2016). This groundwater has been used for irrigation through 650 hand-dug wells, allowing people to produce fruit and vegetables, which are locally consumed or sold at the market (Fenta et al. 2019). This improves nutrition and household food security and generates additional income for households, which reduces poverty (Biedemariam et al. 2017).

Exclosures as a model for dryland restoration

Used widely in Abreha We Atsbeha watershed, exclosures (or area exclosures) are community-managed areas where activities such as free grazing and tree felling are excluded. This practice is well established in Tigray, with some 1.5 million hectares in plots from 1 to 700 hectares, usually on steep and eroded areas previously used for grazing livestock. In Tigray, planning, implementation, management, monitoring and evaluation of exclosures involve local, regional and federal institutions. At the local level are tabia (local) council members and woreda (district) development agents, local and international NGOs, and community watershed teams. Community members, government agencies and NGOs jointly develop local bylaws to be accepted by the community and their social groups, enforced through social fencing and social sanctions such as pressure on "free riders" by not attending their weddings, or excluding them from safety net payments. Bylaws include criteria for rule violations and fines, membership conditions, roles and responsibilities, and benefit-sharing arrangements.

Two complementary approaches are used. The biological strategy simply protects an exclosure from livestock and human interference, with no additional management and natural regeneration from seeds and stumps. The more common assisted strategy involves planting seedlings produced in community nurseries, and constructing soil and water conservation structures such as bench terraces, stone bunds, infiltration galleries and micro-basins. To restore the soil seed bank, grass harvesting is normally restricted to once a year, and doesn't start until in the second or third year after planting, once grass has regenerated sufficiently. Honey production and the collection of medicinal plants are also allowed. Management and protection are effective when local communities and local government take an active part. Many different research studies in Tigray have shown that exclosures effectively reverse land degradation, reduce soil erosion and siltation of micro-dams, increase soil fertility, sequester carbon, and improve ecosystem services and livelihoods. However, communities commonly found that they could not harvest wood fuel or other materials from exclosures as they had hoped, and meeting their desire to extract economic benefits from these exclosures has been challenging. To address this, there is a need to balance economic and environmental benefits; otherwise, communities resort to illegal practices to meet basic household requirements.

As part of the African Forest Landscape Restoration Initiative (AFR100), the Ethiopian government has pledged to restore 15 million hectares nationwide by 2030, with half of this to be achieved through new exclosures. To scale up the successes seen in Tigray, enhanced local governance is needed that must offer communities autonomy over exclosure management, and that exclosures must provide local people with tangible economic as well as environmental benefits.

This landscape restoration initiative in the watershed of Abreha We Atsbeha has improved the resilience of the community. It has enabled the community to better absorb economic and environmental shocks. Furthermore, it has also enabled community members to adapt to and mitigate the ever-changing climate. For instance, as mentioned above, landscape restoration has increased groundwater recharge in the area. Before the restoration work, groundwater was found at a depth of 50 metres, but now it is found only 5 metres below the surface (Gebregziabher et al. 2016).

A simple hand-dug well in Abreha We Atsbeha watershed. Photo: E. Ludi

The combined impacts of the landscape intervention have contributed to reducing poverty and improving livelihoods. This is evident in the 80% reduction in soil loss, the 20–50% increase in cultivated area, the 300% increase in crop production and the 100% improvement in fodder availability (Evans et al. 2012). Farmers were also able to modernize their houses; 79% of sampled households in the village have invested in improving their roofs with corrugated iron (Haileselassie 2013), and have also been able to invest in improved furniture and furnishings (Hagazi et al. 2019).

Benefits for women and youth

Women and girls have benefitted greatly from restoration activities. Before 1998 they had to walk long distances to fetch water and collect firewood, but now they are able to get these resources close to their homesteads. Women are not only beneficiaries; they also contributed their labour to terracing and other restoration activities. This contribution was possible because specific mechanisms were developed to involve women in planning, implementing and monitoring the initiative. Equally important, youth also benefitted from restoration in a number of ways. This ranged from getting more food and more nutritious food each day, and improved access to education, as their parents could pay their school-related costs with income generated from the sale of fruit and vegetables produced through irrigation. Youth groups were also allowed to use the rehabilitated landscape for income-generating activities such as beekeeping. Recently graduated youth groups in the village have formed a cooperative and were given a government nursery to generate income by producing and selling seedlings of species that are preferred by the local community.

The village leader Aba Hawi was once asked if the landscape restoration could create new land and productive lives for youth. He confidently responded that it would. The justification he gave was that

A young boy collecting guava from his family farm in Abreha We Atsbeha. Photo: The community

the youth in Abreha We Atsbeha village, compared to those in the nearby villages without interventions, now have several income-generating activities, such as irrigation of commercial commodities, livestock fattening, dairy production and beekeeping. These are major sources of income for youth; as a result, individuals from this village witnessed that "no one is willing to migrate to other areas," noting that 90% of youth from Abreha We Atsbeha were staying in their village. Restoration also contributes to improved fodder availability for livestock using the cut-and-carry system. Moreover, it has also increased fuelwood availability through the establishment of woodlots and agroforestry in the surrounding area. In addition, the community was able to reduce the consumption of firewood through the use of fuel-efficient cooking stoves (Fenta et al. 2019). Finally — but very importantly — the landscape restoration has its own local bylaws and this has greatly reduced conflicts between villagers.

Spillover benefits for neighbouring villages

Neighbouring villages also benefitted from groundwater recharge, which they use for irrigation. Besides this they could learn from the restoration experience of Abreha We Atsbeha. Furthermore, the check dams and percolation ponds that were constructed greatly contributed to reducing soil erosion and thereby prevented sedimentation problems in downstream areas. Also, a pipeline 14 km long was constructed in 2015 between Abreha We Atsbeha and the town of Wukro; that town now receives a supply of drinking water as a result of restoration and increased infiltration.

Is this kind of landscape restoration sustainable?

Many landscape restoration projects perform well when there is external financial support, but find it difficult to continue in post-project phases with only the resources of the local community. However,

Abreha We Atsbeha was able to sustain the landscape restoration initiative at the watershed level with internal resources, through developing ownership among the local community and community members continuously investing their free labour. This was possible because the local community clearly perceived the multiple benefits of the landscape restoration initiative. However, this initiative also has problems that can hinder its sustainability: some of the structures can be damaged or even destroyed by heavy rainfall.

Global recognition, awards and documentaries

The local community tirelessly implemented landscape restoration, but at the start it was not easy to convince the whole community of the potential success of the restoration techniques. However, the majority of people committed themselves to restoration in order to be able to stay in the village and create better livelihoods. It did not take long to see the benefits of their efforts. Quite soon, the village of Abreha We Atsbeha had a reputation as one of the most successful examples of restoration in Tigray Region. Thousands of farmers from the region and from other parts of Ethiopia have visited the village to learn from its experience. In addition, many middle and top government officials from Ethiopia, as well as representatives of many donor agencies and research institutions, have visited the village, which has always been ready to share its experience. The community has won regional and national awards, and in 2012 was awarded the United Nations Development Programme Equator Prize, given in recognition of its efforts to achieve "sustainable development solutions for people, nature and resilient communities." The restoration experience of the village has also been shown in several documentaries made by independent documentary makers on international TV channels such as the BBC.

Key success factors

There were several reasons for the success of the restoration initiative.

- Implementation had the active participation of the local community; i.e., it was community-led restoration.
- Restoration produced short- and long-term economic and environmental benefits.
- It systematically included women, girls and youth in restoration activities.
- The former village leader had the leadership capacity to mobilize the local community.
- The area has steep slopes producing runoff and sandy soils in the valleys with high rates of infiltration.
- The local people had the ability to change their attitudes/mind-sets from one of dependence to self-help.
- There was participatory development of locally agreed bylaws that support landscape restoration.

Conclusions

Abreha We Atsbeha watershed was one of the most degraded in Tigray. Soil erosion and water scarcity reduced agricultural production, and the community faced food shortages for many years. The government gave them two alternatives: resettle in another faraway region with higher production potential or restore the productive capacity of the degraded watershed. The local community thoroughly discussed the two options, and the village leader, Aba Hawi, managed to convince the local community to choose the second option.

A hillside area exclosure in Abreha We Atsbeha . Photo: Dawit Gebregziabher

Once the local community opted to rehabilitate their degraded land they continuously invested their labour. As a result of this ongoing effort they succeeded in reversing land degradation. The restored productive capacity of the land — coupled with increased groundwater recharge — has significantly increased and diversified agricultural production. As a result, the local community has become food secure and also less poor, as the villagers don't have to sell assets to generate money to buy cereals; instead they generate income from selling cash crops grown in the newly irrigated area. The youth in the village are also now able to generate income from the sale of vegetables from new irrigated plots, livestock fattening, dairy production, and beekeeping. Crucially, the participation of the youth in these income-generating activities has enabled most of them to remain in their village, rather than migrating to cities or abroad, as used to be so common.

The keys to successful landscape restoration from this example are the active participation and ownership of the local community in restoring degraded landscapes, leading to a change in their attitudes; and the leadership quality and communication skills of the village leader. The landscape restoration process must be inclusive in scope and practice, and must consider marginalized groups such as women, girls and youth. The current international attention being paid to drylands landscape restoration can be translated into further success when it better combines economic and environmental benefits for sustainability.

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History and impacts of dryland restoration in Yatenga, Burkina Faso

Adama Belemviré, Mathieu Ouedraogo, Chris Reij & Gray Tappan

Ousseni Kindo and his millet harvest on once barren land, restored using *zaï* pits, contour stone bunds and farmer managed natural regeneration. Photo: Chris Reij

"A better integration of dryland agriculture and livestock became possible only after the emergence of land restoration."

Introduction

Between 1977 and 1987, the French geographer Jean-Yves Marchal wrote about rapid demographic growth, the expansion of agriculture into marginal land, low and declining crop yields, and the destruction of vegetation in the ancient Yatenga region. These effects were also characteristic of the entire northern part of the densely populated Central Plateau of Burkina Faso. In addition, falling groundwater levels forced villagers to deepen their wells almost annually, and many wells dried up at the end of the rainy season. This caused substantial hardship, especially for women, who were responsible for supplying water for their families.

The huge environmental and agricultural crisis of the 1970s and early 1980s triggered a reaction from farmers and NGO staff that

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led to some of the technical breakthroughs in restoration. This article presents restoration techniques used over a 35 year period in the village of Ranawa in Yatenga, and their socio-economic, environmental and livelihood impacts. See Figure 1.

Figure 1. Location of the village of Ranawa in Yatenga Region, in the western part of the Central Plateau of Burkina Faso

The first restoration projects in Burkina Faso

Marchal (1979) analyzed the failure of the first large-scale restoration project in Burkina Faso, implemented in Yatenga from 1962 to 1965. Funded by the European Development Fund, the *Groupement Européen de Restauration des Sols* used machinery to construct soil bunds over 120,000 ha, following all technical protocols. But these were not maintained by the "beneficiaries" and some people even destroyed them, with Marchal remarking that this project treated land as if people did not live there, since local famers were not involved.

The project was perceived as such a failure that it took almost 15 years before another donor, the World Bank, decided to invest in restoration through the Rural Development Fund. This project also constructed soil bunds, but on village farmland; however, although it used a more participatory approach, the project soon ran into similar problems. Then, around 1985, the approach shifted from constructing soil bunds to building contour stone bunds, tested in the early 1980s by an OXFAM-funded agroforestry project in Yatenga. Farmers were keen to adopt contour stone bunds, sometimes in combination with improved traditional planting pits (*zaï*), because they require less maintenance than soil bunds, and farmers saw improved crop yields when harvesting runoff from a slope.

Reactions in the 1980s to the agricultural and environmental crisis

In 1980, no one really knew what to do to reverse the processes of land degradation on Burkina Faso's Central Plateau. But farmers and NGO technicians began to experiment with a range of restoration techniques, and produced several technical breakthroughs (Reij et al. 2005). This includes a widely-published story that around 1980, a farmer in Yatenga region, Yacouba Sawadogo, began experimenting with a traditional technique called *zaï* to restore degraded land. *Zaï* are small planting pits dug into bare and crusted soils at the start of the rainy season. His innovation was that he made the planting pits bigger so that they could contain more water, dug them during the dry season, and added manure to concentrate water and soil fertility in each spot. This technique has since been used to restore tens of thousands of hectares in Yatenga and elsewhere in the Central Plateau as well as in parts of Niger.

Farmers used to put stones in lines on their fields to control runoff or to mark plot boundaries. In the early 1980s, an OXFAM-funded agroforestry project started to improve this technique by putting stone lines along contours, and by improving the construction of the lines, which increased their efficiency in slowing runoff and increasing rainfall infiltration. The project also trained villagers in the use of a simple technique to enable them to determine contour lines themselves; this technique has spread widely on the Central Plateau.

Until the emergence of improved *zaï* pits and contour stone bunds, projects considered that runoff caused erosion, so field teams always tried to divert runoff away from cultivated fields. The main objective of *zaï* pits and contour stone bunds was different: not to reduce erosion, but to harvest rainfall and runoff to increase the water available for crops. This makes sense in drylands, where years of adequate rainfall alternate with years of low and irregular rainfall. Soil and water conservation handbooks explain that work should start at the highest point of a slope and work downwards, to help avoid the destruction of conservation works from erosive runoff. But farmers in Yatenga ignored such handbooks; they first constructed contour stone bunds in their fields at the lowest points to harvest the most runoff, and gradually worked their way up the slopes.

Farmers in Yatenga and in other parts of the Central Plateau rapidly adopted *zaï* pits and contour stone bunds, even though these techniques required a considerable investment in labour for construction. There is limited published data on how much land has been restored using these techniques, but 300,000 hectares was estimated to have been restored to productivity in the Central Plateau alone (Ouedraogo 2005).

What explains the rapid adoption of these techniques? What kinds of impacts do they generate? An important impact of *zaï* pits is that they help to restore very degraded land whose productivity is otherwise close to zero. In areas with high population densities, such as Yatenga (100+ inhabitants per km^2), where there is considerable pressure on available resources, the possibility to expand farmland is very attractive to family farmers.

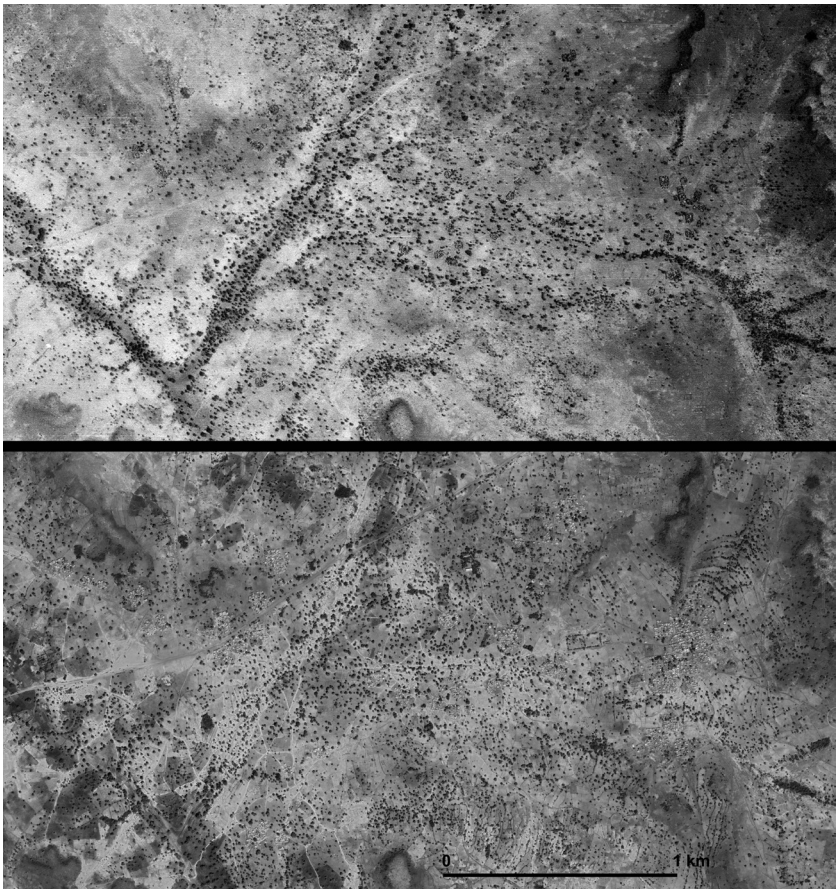
The multiple impacts of restoration in Ranawa (1984–2020)

During the long October to June dry season, women always had to walk long distances to fetch water, and most families also endured significant food shortages during this period. Between 1975 and 1985, one-quarter of Ranawa's people left; most migrated to southwestern Burkina Faso, with higher rainfall

and more fertile soils. But during the dry season of 1983–84, the OXFAM-funded agroforestry project introduced *zaï* pits and contour stone bunds and continued its support for several years.

Land use

The introduction of restoration techniques in 1984 led to a village-wide transformation of land use and vegetation, illustrated in aerial and satellite images taken in 1984 and 2019 of 820 hectares of the Ranawa *terroir* (traditional land area), almost all of which was cultivated (Pictures below). Standard visual image analysis was used to identify and measure areas where stone bunds were present, and to quantify tree cover. In 1984, there was 12% tree cover, and 11% of the area was treated with contour stone bunds. This increased to 19% tree cover and 56% under bunds by 2019. This level of tree cover is quite high: two to five times greater than in regions well known for farmer managed natural regeneration, including southern Niger and Mali (Reij et al. 2009). Stone bunds slow runoff and increase infiltration, with highly visible and positive impacts on tree regeneration, and the linear patterns show that they are a major factor in increasing tree cover (Pictures below).

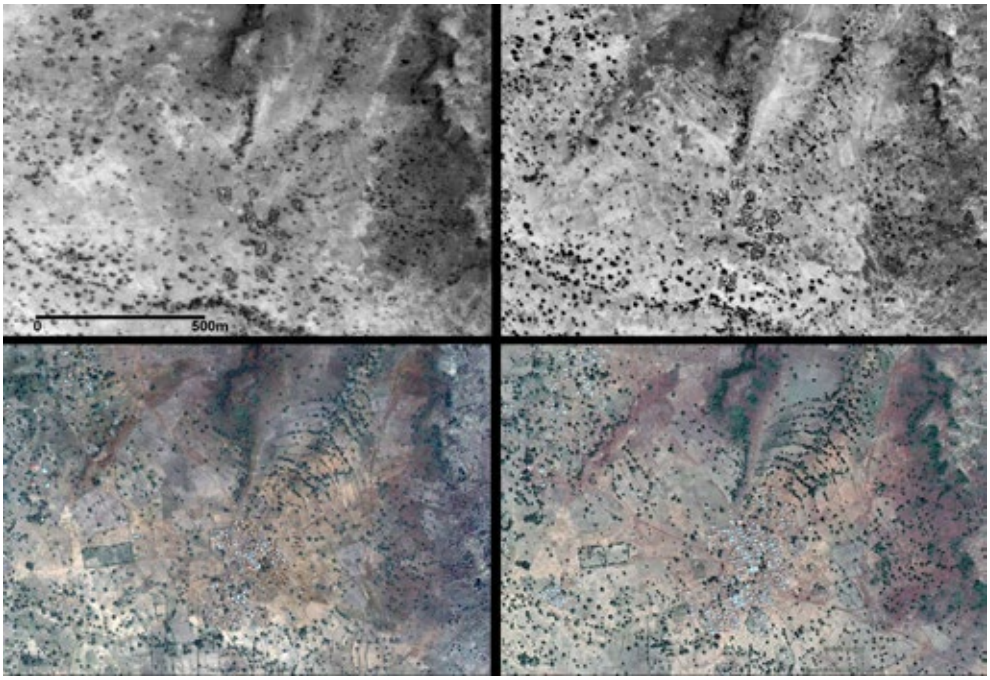


The Ranawa terroir landscape in 1984 (top) and 2019 (bottom), both in the dry season. Note the increase in overall tree cover, with growing villages visible, and linear features representing stone bunds. Sources: Institut Géographique du Burkina Faso (top); Google Earth (bottom)

The parkland pattern near Ranawa also changed over time. In 1984, dense tree cover tended to concentrate along seasonal water courses and low-lying areas. But by 2019, parklands had become much more widespread over all land uses and areas, with the spread of trees correlated with the increase in land treated with stone bunds. Many fields that were treeless in 1984 were transformed into dense agroforest parkland by 2019. In June 2020, villagers confirmed that on-farm tree densities were still increasing and that trees were producing more fruit, fodder and fuel on restored land than those on adjacent fields. See pictures below.

Groundwater recharge

In 1984, all wells in Ranawa dried up at the end of the rainy season, but the situation improved rapidly in the years following the implementation of water harvesting techniques such as planting pits and contour stone bunds. A survey in 2002 showed that all wells in the village continued to retain water for the entire year, and in June 2020, this was still the case. A new development is that several families have dug wells on their own farmsteads. Villagers attribute the increase in water not to greater rainfall, but to the contour stone bunds and *zaï* pits. People in other villages who invested in restoration also reported an increase in water levels in their wells. This increase in water occurs only in restored areas or immediately downslope, whereas if rainfall was a decisive factor, wells upslope of restored areas should also see a rise in water levels. Given the lack of water in Ranawa before 1985, vegetable gardens were not an option. Today the village has six vegetable gardens that have been developed around wells (exploited by mixed groups of men and women) and at least seven irrigated gardens owned by individuals.



A time series over 35 years in northeastern Ranawa, all dry season: 1984 (upper left), 1996 (upper right), 2002 (lower left) and 2019 (lower right). Sources: Institut Géographique du Burkina Faso (top); Google Earth (bottom).

Crop yields

There are no data for cereal yields in Ranawa, but from the village of Somyaga, 40 km to the north, which is similar in terms of rainfall and soil conditions, there was a huge difference in yields between a control plot where no restoration techniques and plots treated with manure and stone bunds, *zaï* pits or half-moons (small earth embankments in the shape of a semi-circle); see Table 1. In June 2020, the perception of villagers was that most are food secure during the entire year and households generally eat three meals a day; this was not the case before 1985, and now some people even produce a surplus for sale.

Table 1: Impacts of restoration techniques on sorghum yields (kg/ha) in Somyaga village over 3 years.

	2016		2017		2018	
	718 mm rainfall		625 mm rainfall		889 mm rainfall	
	grain	stover	grain	stover	grain	stover
control plot	128	706	54	324	262	1,047
stone bunds	769	1,857	612	1,628	952	2,008
zaï pits	1,384	3,156	1,046	2,947	1,489	3,917
half-moons	1,521	3,485	1,312	3,006	1,634	4,022

Note: 5 tonnes per hectare of organic matter were applied to all treatments except control plots.
Source: Sawadogo and Serme (2020)

Livestock management

Before 1985 most smallholders kept some goats or sheep, but only a few owned any cattle. Today every household has cattle and most keep their livestock tethered, a huge change from the past when free grazing was the norm. Enclosing livestock became possible because more crop residues and tree foliage were available as fodder, and this in turn increased manure availability, to help maintain or improve soil fertility. Villagers also more clearly see that livestock are part of a holistic system, where animals support agriculture through manure and draft power for tillage, and agriculture supports livestock through fodder. In 1980, agronomists emphasized the need to better integrate agriculture and livestock, but this did not happen. It was only after the emergence of land restoration techniques that integration became rational and possible.

Soil fertility

Traditionally, farmers applied most available manure on plots closest to their homesteads (*champs de case*) with the highest crop yields. Less manure was used on village fields (*champs de village*) and none at all in more remote bush fields (*champs de brousse*). However, most restoration investments were applied to bush fields and this is where farmers began to concentrate manure. In recent years, the highest crop yields were on bush fields, surpassing those on homestead plots.

Demographic dynamics

Ranawa lost 25% of its population between 1975 and 1985, but its population doubled between 1985 and 1996. Since the start of restoration in 1984 not a single family has left the village, and many who had left and settled elsewhere chose to return, since productivity and possibilities had significantly improved. More than half of the 20 participants who met the authors in June 2020 to discuss the current situation in the village were among those who had returned.

Rehabilitated agroforest landscape in Ranawa (2008); this land was barren in 1984. Photo: Chris Reij.

Conclusions

Since the mid-1980s, the positive impacts of these simple, cost-efficient water harvesting techniques have become clear, following their increasingly widespread adoption. Their use has allowed smallholders to reverse land degradation, improve soil fertility, sustainably increase crop production, achieve food security, and create more productive, diverse and resilient farming systems. At the same time, groundwater is recharged, improving access to drinking water for the entire year, and creating opportunities for irrigated vegetable gardening around wells.

The people of Ranawa faced an existential crisis in 1984, but today they are less poor, better fed, better clothed, and better housed. Every family in the village now has the cash to invest in at least one mobile phone, indicating that they are also better connected. Would this transformation have been possible without their efforts to restore the productive capacity of their village lands?

The combination of planting pits and contour stone bunds has helped to effectively restore degraded land in the village of Ranawa and in many more villages in the northern part of Burkina Faso's Central Plateau. How scalable are these techniques? The construction of contour stone bunds obviously requires the presence of stones close to the farmland. The *zaï* planting pits function well in conditions of 400–800 mm rainfall. Rainfall below 400 mm would require much bigger pits to hold more water and rainfall greater than 800 mm risks drowning the crops in the pits. *Zaï* pits have also been used to restore degraded land that is flat and has a hard crust.

As the construction of contour stone bunds and the digging of planting pits require an important investment in labour, they are usually found in areas with high population densities (30+ persons per

km²). In 1989, 13 farmers from Illela district (Tahoua Region) in Niger visited Yatenga region, and on their return, began to experiment with planting pits. Thereafter, planting pits were widely adopted in that part of Niger (see case study in this issue: Post-project impacts of restoring degraded land in Tahoua, Niger). Planting pits and contour stone bunds are simple water harvesting techniques that do not require massive investment, and have the potential for scaling to other dryland areas across the Sahel and the Horn of Africa where the conditions mentioned above are met.

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Two decades of farmer managed natural regeneration on the Seno plain, Mali

Mary Allen, Mamadou Diakhite & Drissa Gana

Millet stalks in *Faidherbia albida* parkland between Koro and Bankass. Photo: Chris Reij

"Farmers reacted quickly to the 1995 forest law that recognized their rights to on-farm trees, with remarkable results."

Introduction

Bankass and neighbouring districts in the Seno plain of Mali were part of a largely treeless landscape in the 1980s. Farmer managed natural regeneration (FMNR) has been promoted since the early 2000s by SOS Sahel UK and subsequently by the NGO Sahel Eco. By 2010, FMNR had resulted in the significant regrowth of trees on an estimated 450,000 hectares of land (Sahel Eco 2019), mostly on rainfed millet fields and short-term fallows. Tree densities of more than 250 trees/ha are now recorded.

This article cites data from a previous study (Allen et al. 2009), supported by more recent observations (Sahel Eco 2019).

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Both individual and collective actions were promoted by Sahel Eco. For individual farmers, this included four main tasks:

- cleaning around seedlings and coppice shoots and removing dead grass and leaves to avoid possible fire damage;
- marking seedlings and regrowth clearly, and avoiding uprooting them by lifting up the plough blade when passing;
- thinning regrowth to adequate spacing, while retaining only one or two strong shoots on each seedling; and
- pruning when trees are large enough so crops receive more light, that also provides a harvest of fuelwood.

Collective actions included prohibiting the use of fire; developing and enforcing community bylaws that support FMNR, in collaboration with the forestry service; and awareness raising and promotion of the widespread adoption of FMNR techniques.

Uptake of FMNR

Of almost 500 farmers interviewed in four villages (Allen et al. 2009), 84% of them had adopted FMNR by 2008. The most common reasons for adopting FMNR was that trees helped protect soil from wind erosion (stated by 15 of 24 heads of households interviewed) and increased soil fertility (half of the interviewees). Other reasons, such as the provision of fuel, fruit and shade, were secondary, and mentioned by only a few farmers, the vast majority of which were male heads of household. When asked how they had learned about FMNR, one-quarter of them noted that it had been practised traditionally in their village. Training received from the national agricultural extension services and SOS Sahel UK was mentioned by one-third of the farmers, and a similar number spoke of the awareness-raising activities carried out by the local traditional Barahogon association; some people learned about FMNR techniques while listening to the local Radio Seno.

Typically, the head of household decides whether to adopt FMNR, but interviewees said that it was equally important to raise awareness among women and youth, since they provide most agricultural labour and play a key role in implementing FMNR when ploughing or hoeing family fields. In 2008 most interviewees (78%) were satisfied with the outcomes of FMNR, but some thought the local association could be doing more to support them. They indicated that the surveillance of village land was not as intensive as it had been when they started, that some fraudulent wood cutting continued, and that the association lacked the resources to patrol every day.

By 2019, the percentage of farmers practising FMNR had increased to 90%, an estimated 50% increase over a 20-year period. FMNR was only one of a range of restoration practices promoted in the area; adoption had also increased for almost all of them (Table 1). It is notable that bush fires had been almost entirely eliminated by 2019, and that tree planting was limited in many villages by a lack of water. Also, agricultural intensification included a range of practices, such as improved seed, targeted fertilizer applications, and various soil and water conservation techniques.

FMNR in high density *Combretum glutinosum* parkland in Bankass district. Photo: Chris Reij

Table 1. Change in adoption of restoration practices in the Bankass area, 1999–2019

Practices	% adoption in 1999	% adoption in 2019	Change in %
Reduction of fires/burning	50	100	+50
Farmer managed natural regeneration	40	90	+50
Improved land clearance	20	70	+50
Intensification of livestock production	20	70	+50
Intensification/diversification of agriculture	20	60	+40
Improved stoves	10	40	+30
Soil and water conservation	10	40	+30
Reforestation	40	50	+10
Production of tree seedlings	10	30	+20
Organization of fuelwood exploitation	20	20	0

Source: Adapted from Sahel Eco (2019)

Impacts of re-emerging parkland agroforests

The effect of FMNR on vegetation is clearly seen in the area between the small town of Bankass and the village of Endé, where it has been practised for longer by villages belonging to the Barahogon association. In 2008 quantitative data was gathered of the effects on tree cover using a simple inventory, and local knowledge was used to identify the impacts on flora and fauna, using participatory tools that enabled communities to make these evaluations (Allen et al. 2009).

The data showed that the restored agroforests had an average density of 277 trees per hectare, dominated by *Combretum glutinosum* (82%), with *Gueira senegalensis* and *Balanites aegyptiaca* making up a further 10%. Farmers also noted that of the 49 species of trees, grasses and wildlife they identified as most useful to them, 35 were observed to be increasing in frequency. Analysis of distribution by trunk diameter confirmed that agroforests were dominated by young trees or recent regrowth, with 95% of all trees estimated to be less than 10 years old. The benefits of FMNR seen by local communities included more fuel and timber to meet their needs, more animal fodder from browse and undergrowth for their herds and for visiting herds, income from selling surplus cut grass in nearby towns, and the protection of young millet crops from wind and water at the start of the rainy season.

Elsewhere in the region, farmers actively manage a mix of regenerating species. In neighbouring Koro District, FMNR thrives on both sides of the road to Burkina Faso and *Faidherbia albida* is an important species in many places. This may be due to the influence of an earlier agroforestry project run by CARE Mali, which actively promoted the protection of this species in collaboration with the traditional association Ogokana (Boffa 1990; Kerkhof 1990). In Bankass District, it was individual farmer innovators such as Boucary Guindo who first began to selectively regenerate *Faidherbia albida* to improve soil fertility (see below).

The power of example

Boucary Guindo lives in Ogossagou village. In 2004 he started to protect naturally regenerating trees in his fields after hearing about the experiences of the Barahogon association. But he wanted to grow more *Faidherbia albida* trees (called balanzan in Mali), since they increase crop yields. There were very few mature trees nearby, so he decided to give natural regeneration a helping hand by collecting the pods, feeding them to penned sheep and goats and then planting the manure and pre-digested seed mixed in pockets on his fields. Boucary said that only two other neighbouring families did the same, and most people thought he was crazy. Later, he persuaded the village chief to introduce a rule that people can cut trees only in fields that they themselves cultivate. He believes that this will pave the way for many more households to adopt FMNR techniques in the future.

During a three-day workshop and parallel interviews in Bankass District in 2008, local farmers noted improved millet harvests, resulting from both the physical protection of soils ("winds no longer bury millet shoots") and enhanced soil fertility ("leaves decompose and enrich our fields"). Farmers also observed that so much more grass and foliage was available for livestock in the dry season that a surplus could be cut and sold. FMNR reduced the time and effort required for women and girls to collect fuelwood, since they can now use the branches that the men prune from trees when preparing their fields. And farmers also noted that there was less tension (fewer conflicts) between villagers over natural resources, and stronger relationships had developed.

Interestingly, the findings suggested that farmers who cultivate fields that are "borrowed" from the families who first occupied and cleared the land have also adopted FMNR techniques, despite tree planting being strictly forbidden by customary tenure arrangements. This indicates that "first occupant families" have accepted FMNR as a mark of good stewardship of their land, rather than as something that will undermine their customary rights.

Fuelwood from naturally regenerated trees. Photo: Sahel Eco.

Lessons learned

These six factors were seen to have contributed to successful tree regeneration in the area between Ende and Bankass.

- *A favourable institutional and legal context*. This included the introduction of multi-party democracy in 1991, followed by decentralization of local government, the revision of the forestry law in 1995, and the first municipal elections in rural areas in 1999.
- *A tradition of environmental protection at the community level*. Local people consider members of the Barahogon association to have a legitimate role in drawing up and enforcing regulations that govern access to natural resources.
- *A core group of enthusiastic and committed people*. These people from the village of Ende took the initiative to revive the local Barahogon institution by building support in neighbouring villages, registering the association, defining its bylaws and initiating patrols.
- *Training of the local association and other key stakeholders*. This included training in forestry legislation, and in basic literacy in their local language, and exchange visits to learn about field tree management techniques.
- *Ongoing moral support from local community leaders, politicians and NGO staff*. This was particularly important when communities challenged the practices of others, such as foresters and wood cutters from nearby towns.
- *Use of innovative communications*. A local-language film, radio broadcasts and brochures allowed information to be disseminated widely in the Mopti region, and a strategy for wider-scale dissemination within Mali and across the Sahel was proposed.

Award presentation by Sahel Eco to recognize regreening champions. Photo: Sahel Eco.

Informing future activities

The effectiveness of future activities can be increased by taking account of the following considerations, and the single most important factor that limits the adoption of good agroforestry management in Mali is the widely held misconception that farmers do not have any rights to protect and control access to the trees on their land. In 1999, when a senior forester confirmed this with local leaders from Ende, they decided to organize themselves and take action. They paid for announcements on the local radio station to inform neighbouring villages that — with or without an official permit— non-residents would no longer be allowed to cut firewood or timber on their agricultural land. With the support of village chiefs, they also introduced a community bylaw forbidding the cutting of trees on fields or fallow land without permission from the respective head of household. This simple rule is strictly enforced, but each head of household is free to decide whether or not to adopt FMNR techniques on his or her land.

Enabling legislation is necessary, but does not in itself necessarily bring about the desired changes in behaviour. To be effective, the introduction of a new law must be accompanied by discussions among all stakeholders to ensure they have a shared interpretation of how the law will be applied, enforced and evaluated. Mali's 1995 forest law, for example, allowed farmers to manage their own agroforests, but the forestry service did not give any clear instructions about how this should be done. Furthermore, foresters were evaluated on the income they raised from selling timber permits and levying fines, undermining any incentive they might have to promote FMNR.

Good agroforestry practices should be promoted as an essential component of improving agropastoral production systems and enhancing food security in the Sahel. This was the principal motivation for farmers in Bankass to adopt FMNR and invest in tree protection, with increased fuel and fodder supplies being key to ensuring that women and herders also benefitted.

Community regulations and enforcement systems must be perceived as legitimate by local people. This is best achieved by building on traditional institutions, where they still exist and are respected, and by ensuring that women and herders (resident and transhumant) are involved when drawing up appropriate rules of access. New systems must not contradict any formal legislation, but they do not necessarily need to be written down. Formal endorsement of local conventions or adoption of bylaws by the local municipal council may help to secure compliance in the long term, particularly by "outsiders," but this has yet to be tested in Bankass.

Training, information and other support activities should target elected local government officials and state administrative and technical staff as well as farmers. Training should include the district judge and agents from the agriculture and livestock extension services, as their support is crucial to the widespread adoption and success of FMNR. In addition, joint training sessions and exchange visits are useful for building relationships and developing alliances between community representatives, local government officials and civil servants.

Conclusions

The adoption of FMNR increased by 50% over 20 years; about 90% of all farmers now encourage natural regeneration on the land that they manage. The key to success is having local institutions that are respected and effective. The experience in Bankass shows that reforestation rates of at least 250 trees per hectare can be achieved by farmer managed natural regeneration on Sahelian agricultural lands, recreating an agroforestry parkland at a fraction of the cost of establishing conventional plantations. Lessons learned about FMNR and key factors for its success include the critical importance of effective local institutions and of their good working relationships with communes, community-based associations, government extension services, and NGOs.

The Barahogon traditional association was formally registered 20 years ago and has been promoting FMNR ever since. The strength of these traditional institutions is remarkable, given the constantly changing context, including the adoption of new legislation and regulations, the near-doubling of the sedentary population in the area, added pressure on access to land and natural resources, and increased security concerns.

The current situation in Mali has exacerbated intercommunity tensions, in particular between the Dogon (traditionally farmers) and Peulh (traditionally pastoralists) (Toulmin et al. 2020). Also, because one of the country's jihadi leaders is Peulh, many people assume that all Peulh are jihadists, and there are accusations of extrajudicial killings by the military and of attacks by local militia from both sides. Due to this deteriorating security, the management of natural resources is a lesser priority for local communities, whose lives and livelihoods face more immediate threats. Many people — both Dogon and Peulh — have fled the district, and some may never return. If local institutions are to continue to contribute to the management of natural resources, they will require backing from national and local authorities. This must be well financed over the long term, and supported by capacity building and training for their leaders.

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Farmers working together to restore their degraded land and diversify production

Beverly Mugure Gichiri

Cattle benefitting from improved water sources. Photo: Beverly Mugure

As a farmer in northern Kenya, I came to understand the importance of dryland restoration. After moving to Kaijaido country in the south, I started an initiative to restore the land, increase food security and reduce poverty, supported by a grant from the East African Community with various activities supported by FAO and Yale University.

The local Maasai people are pastoral. They depend on pasture and browse trees for their livestock, but most land is now so degraded that this has led to hunger and hopelessness. I began by mobilizing the community and training them in the importance of land restoration. The aim was to foster relationships, learn by doing, and share and co-create knowledge on how to effectively and sustainably restore degraded land, in order to increase profitability and landscape and livelihood resilience.

The community's commitment was clear. They never missed a training session, which sometimes were held every day for a month, and this was key to the project's success. Training was done in different areas, with women's associations, schools and religious organizations in marketplaces and town centres, with local government, and private agricultural organizations. Kenya Red Cross supported costs for facilitation, volunteers, transport and learning materials. There were many challenges,

Beverly Mugure Gichiri, farmer, Kajiado County, Kenya

though, including language barriers (many Maasai women don't understand English and only some speak Kiswahili), poor roads, lack of water, and scarce finance. But the involvement of local government, an educational institution and a women's group was a great help. Many youth and women felt empowered and became interested in starting small agricultural projects themselves, to boost the local economy and tackle environmental challenges. This included vegetable growing, beekeeping, poultry production, tree planting, waste management, water conservation, fish farming in the newly constructed ponds, and even insect farming — raising crickets and termites for livestock feed.

Land restoration has had a great impact, with farmers taking active leadership roles. As a result, there is increased food production and reduced hunger, and the community members have mastered ways to conserve water by building small dams, which also increases production and biodiversity. I have seen a change of mindset among youth, and community resilience in their newfound ability to organize themselves and tackle climate change. At the international level, people can surely boost land restoration in Africa by focused incentives, introducing carbon prices, leveraging climate finance to mitigate risks, and educating communities to build self-sustaining agricultural projects.

A young farmer sowing vegetables after learning horticulture from other farmers. Photo: Beverly Mugure

Adoption of farmer managed natural regeneration in Senegal

Robert Winterbottom, Mike McGahuey & Gray Tappan

A Senegalese farmer practicing the technique of farmer managed natural regeneration by pruning smaller coppicing shoots of *Piliostigma* shrubs to favour regrowth of the main stem and increase tree cover on his cropland. Photo: Robert Winterbottom

"Successful restoration of agricultural landscapes can be initiated and sustained by smallholders and rural communities."

Introduction

Valuable lessons can be learned from smallholder farmers who have successfully protected and regenerated tree cover across agricultural landscapes in Senegal, with minimal reliance on tree nurseries, seedling distribution or tree planting. In the process, they have restored soil fertility to sustainably increase agricultural production. Analysing how and where this approach has occurred underscores the importance and feasibility of achieving restoration in ways that contribute to improved livelihoods, reduce vulnerability to climate change and other shocks, and restore ecosystem services. This article highlights a relatively low-cost intervention implemented by rural communities with support from development organizations and that could be widely replicated.

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Farmer managed natural regeneration

Farmer managed natural regeneration (FMNR) is transforming the lives of Senegalese farmers, especially in Kaffrine region. Since 2007, instead of cutting back sprouting shrubs and trees while clearing fields for planting, farmers have deliberately pruned coppice shoots, leaving the largest tree stems to grow, and assisting the natural regeneration of trees in their fields.

According to field staff working with World Vision in Senegal, by May 2019, more than 20,000 farmers across 45 communes in Kaffrine, Fatick and Kaolack had been trained in FMNR. Average farm size is about 2 hectares (ha), and most farmers protect and manage some 40 trees per hectare. In 2015, there were 64,000 ha of FMNR in Kaffrine, increasing to 85,000 ha by 2020. The expansion is attributed to farmers' appreciation of the benefits of FMNR, and continued training and extension (pers. comm., C. McMillan, 2020).

A well-adapted response to farmers' problems

Farmers adopted FMNR to increase soil productivity and reduce vulnerability to climatic and other shocks. Population pressure forced many to reduce or abandon fallowing, their traditional means of soil restoration and a safety net in years of crop failure. Table 1 summarizes key soil and climatic threats, and how farmers have used agroforestry to address these challenges.

Table 1. Threats arising from soil degradation, water erosion and drought and the benefits of adopting FMNR and other agroforestry practices as a response.

Threats	Documented benefits from *Faidherbia albida* parklands, FMNR and other forms of agroforestry
Sahelian soils are nutrient poor, with little inherent capacity to retain nutrients and moisture in crop root zones; they are also prone to surface crusting, low infiltration, and high rates of rainfall runoff.	• Increased nutrient recycling from lower horizons to topsoil • Increased soil organic matter that (a) significantly increases the capacity of the soil to retain nutrients and moisture in crops' root zone, thereby increasing fertilizer and rainfall-use efficiencies; and (b) improves soil structure, thereby allowing greater rain infiltration and air flow • Increased populations of soil microbiota that convert complex compounds to nutrients that can be used by crops • Increased nitrogen fixing by leguminous trees
Dry periods of 10-15 days, along with low retention of soil moisture, increase mortality of newly germinated crops, which then require replanting; shortening the growing season and lowering yields.	• Increased soil capacity to retain moisture in crop root zones • Increased shade, which reduces soil temperature and crop transpiration rates • Nightly transfer of water by trees from deeper soil horizons to crop root zones through "hydraulic lifting"
In periods of periodic drought and other shocks (e.g. pests, market changes), rural families face food shortages, whatever farming practices they use.	• Agroforestry products such as fuel wood, fodder, fruits, condiments, poles, fencing and pharmaceuticals are less vulnerable than annual crops to droughts and other shocks; these products are also sold to support domestic necessities, reducing the need for people to migrate in search of work or to sell productive assets (livestock, equipment, land)

Increased tree cover from FMNR practiced on farmland near Kaffrine. Photo: Robert Winterbottom

Restoration of agroforestry parklands and increasing tree cover across agricultural landscapes clearly help to remedy several critical problems faced by farmers in African drylands.

Benefits and advantages of FMNR

With no reliance on tree nurseries, and no costs for raising, transporting, planting, and fencing planted seedlings, FMNR has many advantages over reforestation through tree planting. The cost of FMNR to increase tree cover on cropland is estimated at US$50 per ha, approximately one-tenth of the cost of planting trees, typically US$500 or more. In addition, there are low survival rates for tree planting. FMNR, on the other hand, takes advantage of existing tree root stocks and vigorous coppicing capacity of native multipurpose trees. Also, investing time and effort in naturally regenerating trees is more attractive for farmers than relying on external assistance for seedling production, transportation, and out-planting, especially as this assistance may no longer be available when projects end. FMNR can also spread following interactions among farmers, with minimal reliance on government forest service agents or other specialists.

FMNR generates tangible and valued benefits for farmers. Pruning rapidly growing shoots and branches from tree stumps provides short-term benefits that are not possible from planted seedlings. In the first year, a farmer can prune and harvest selected branches for fodder and firewood and make green manure from leafy branches to replenish soil organic matter, increasing soil nutrients, soil structure and efficient use of rainfall.

The most common trees regenerated and managed by farmers practicing FMNR include *Balanites aegyptiaca, Combretum glutinosum, Faidherbia albida, Piliostigma reticulatum* and *Ziziphus mauritiana*.

These tree species provide a variety of socioeconomic and environmental benefits, including the production of poles, firewood, fodder, fruit, oil seeds, honey and medicine, improved soil fertility and crop yields. Senegalese researchers measured a 2.5-fold increase in cereal production, from 296 to 767 kg/ha (World Vision 2010). Some farmers have earned an extra CFA100,000–200,000 (US$170–340) annually from selling Balanites oil, Ziziphus fruits, and honey (World Vision 2020).

Increasing smallholder productivity – an important driver of adoption

Research shows that the productivity of Senegal's weathered soils is highly correlated with soil organic matter content (SOM). Traditional soil restoration systems, based on long fallows, allowed farmers to, inter alia, regularly replenish SOM. Population pressure in the 1960s and 1970s, however, forced farmers to reduce or abandon fallows and cultivate continuously. The resulting decline in yields was aggravated by severe droughts in the 1970s that produced a crisis. To increase productivity, the Senegalese government, in collaboration with international partners, increased fertilizer subsidies to encourage fertilizer use as a means to increase productivity. But, over time the yield response to fertilizers declined, demand fell and the continued use of fertilizer, *by itself*, was called into question. Research showed that failure to accompany fertilizer subsidies with ways to increase and maintain SOM levels was a key reason for the failure of fertilizer to be cost-effective (Dancette and Sarr 1984). Absent the multiple services provided by soil organic matter summarized in Table 1, fertilizers will likely perform below their potential on Senegal's weathered soils (Wopereis 2006).

Experience and research show that agroforestry systems provide many of the advantages of fallowing as a soil restoration tool while allowing farmers to continuously cultivate (Felker 1976). This research shows, for example, that the traditional *Faidherbia albida* agroforestry system not only doubled yields and increased the protein content of cereal crops, but significantly increased factors that sustained yield improvements over time. These factors included more soil organic matter as well as nutrient recycling (Felker 1976).

Researchers also noted that *Faidherbia albida* produced high-quality pods (26–28% seed protein) and leaves for livestock browse (Felker 1976). Pod yields were 105–5,400 kg/ha/year, depending on tree age and density. Farmers feed pods to livestock or sell them in local markets, diversifying household income and reducing vulnerability to shocks.

Until recently, many researchers, agricultural extension agents and government policy makers had largely overlooked the importance of trees and shrubs on cropland in relation to nutrient cycling and other ecosystem functions (Winterbottom et al. 2013). In the past decade, however, researchers have documented how the root system of common shrubs such as *Guiera senegalensis* and *Piliostigma reticulata* move water from deeper soil layers to the crop root zones during the night (Dossa et al. 2012). This "hydraulic redistribution" increases moisture available to crops at critical times in their development cycles (Kizito et al. 2012). Shrubs also add organic matter that contributes significantly to the soil microbial population and stimulates nutrient cycling, helping to drive biogeochemical processes year-round in ways that were not previously recognized by agronomists.

Of the many benefits of agroforestry trees, their role as an efficient delivery system for organic matter may be the most important. Senegal's growing population requires greater yields, which will require more efficient use of fertilizers and rainfall to support the regular replenishment of soil organic matter.

Protecting and managing tree regeneration on cropland adds substantial quantities of organic matter in the right place at the right time.

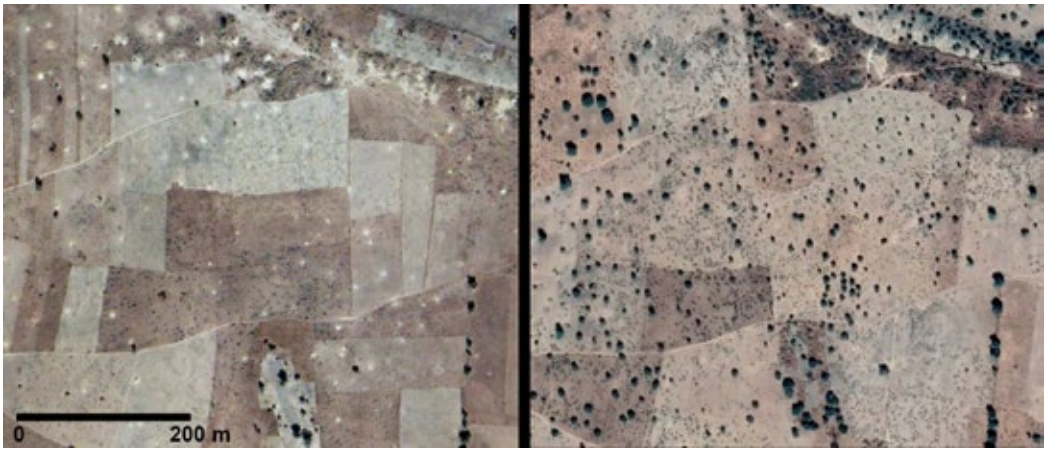
Key interventions to support the adoption of FMNR

For more than a decade, World Vision has supported rural development projects in Senegal to help smallholders increase agricultural production and rural incomes while combatting land degradation and the effects of climate change. These projects initially worked with farmer associations to increase access to fertilizers, and distributed cashew, mango and eucalyptus seedlings. Beginning in 2007, support from World Vision encouraged the adoption of FMNR, including funding for a learning visit that enabled farmers from Kaffrine to talk with those in the Maradi region of Niger and see the extent and benefits of FMNR there. When the Kaffrine farmers returned, they immediately adopted FMNR practices in their fields. When the authors visited several of these farmers in 2011 and 2016, they observed how farmers had enthusiastically embraced the protection and management of natural regeneration in their fields.

National and international development organizations have continued to initiate and accelerate FMNR adoption in Senegal and elsewhere. In addition to international learning visits, key interventions included facilitation of local cross visits between FMNR leader farmers and others in their communities, providing opportunities for farmer leaders to encourage their peers to adopt FMNR, and for farmers to learn about and witness the benefits. Peer-to-peer training and awareness raising through community meetings and radio broadcasts also helped to spread the practice, as did periodic field visits with local environmental authorities to monitor and support FMNR adoption. The formulation and adoption of "local conventions" governing the use of land and natural resources encouraged farmers to practice FMNR by addressing problems of uncontrolled grazing, bushfires and wood harvesting. The effective application of decentralization policies and devolution of authority for decentralized natural resource management were critically important for developing local conventions. Support was also provided for training and strengthening of community-based organizations responsible for enforcing local conventions. Mayors and religious leaders also helped to spread FMNR by drawing attention to its benefits and by facilitating the application of local conventions. Finally, institutional reforms within the Senegal Forest Service and changes in forest regulations also played roles in improving the enabling conditions for the adoption of FMNR.

A Senegalese farmer excited about describing the benefits of FMNR and keen to share his successful restoration experience with his peers. Photo: Robert Winterbottom

All these activities helped to motivate farmers to adopt FMNR and encourage its spread, seen clearly in time-series remote sensing across



A comparative view of farmland east of Korki in December 2002 (left) and January 2019 (right). The dramatic increase in tree cover indicates the active spread of FMNR from farmer to farmer.
Sources: Maxar Technologies with Google Earth

Kaffrine and eastern Kaolack regions. The World Vision Senegal programme certainly had a major catalytic role, and an important driver for the continued spread of FMNR has been farmer-to-farmer communication about the tangible benefits that farmers see from parklands of on-farm trees.

Putting FMNR adoption in perspective

The growing adoption of FMNR in Kaffrine, Fatick and Kaolack regions is at the heart of a new and extensive transformation of agricultural land in Senegal that has led to greener, more tree-covered landscapes in the past 10-20 years. This positive development is not unlike the regreening that began in southern Niger in the mid-1980s, a phenomenon that led to the success story that it is today (Reij et al. 2009; Pye-Smith 2013). These regions in Senegal belong to what is called the "new peanut basin" owing to the recent expansion of rainfed cropland from the original peanut basin. Together with a wave of charcoal production from the 1960s to 1990, the cropland expansion severely degraded wooded savannas on the plateaus and the broad valleys (Tappan et al. 2004; Stancioff et al. 1986). At that time, many farmers deplored the loss of trees and the many benefits that they provide. Tree cover began to increase a decade ago when positive results from FMNR became evident in the fields of early adopters. It is instructive to take a closer look at the changes in the FMNR fields and adjacent ones over the past 18 years using time-series imagery.

Images above present cropland that includes the fields of a farmer who actively began practising FMNR in 2008 upon returning from his visit to Niger. His fields are 1 km east of Korki and 16 km west of Kaffrine city. Most neighbouring farmers did not participate in the visit to Niger but heard about it from the few who went. The paired satellite images show the dramatic change in the density of field trees, from 0.4% tree cover in December 2002 (left) to 5.2% in January 2019 (right), a 13-fold increase. This area of farmland in Senegal now has a tree density equivalent to areas where FMNR has been adopted in southern Niger.

Conclusions

Based on experiences in Senegal and elsewhere across the Sahel, successful restoration can be initiated and sustained by smallholder farmers and local communities. Mobilizing support for cross-visits and farmer-to-farmer exchanges has been especially important in motivating behavioural changes. Support for peer-to-peer training about FMNR and other improved natural resource management practices have also been crucial in enabling smallholders to overcome the biophysical constraints of dryland agriculture, including weathered and leached soils, loss of soil organic matter, highly variable rainfall, and high rates of runoff. Additional capacity building and training in institutional development and enterprise management, and support for decentralized land-use planning, participatory forest management and tenure policy modifications have also been important.

The path to success includes taking steps to strengthen local governance and diversify local economies. The full participation of key stakeholders in community-based land-use planning is essential, together with the devolution of authority to local communities to enable the formulation and local enforcement of rules governing access to and use of natural resources. For restoration to be fully successful requires that stakeholders work together to market the products of protected and managed trees across agricultural landscapes, while providing for equitable benefit distribution (Dororetz et al. 2014). Institutional and regulatory reforms are also needed to establish more favourable enabling conditions, and to provide programme support that addresses factors related to community organization, governance and other aspects highlighted in this example of successful restoration. Using such experiences can clearly inform the required changes, shorten the process, and lead to more effective reforms (Reij and Winterbottom 2015).

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Farmers' strategies for adapting to climate change in Niger

Soulé Moussa & Abasse Tougiani

Urban farming in the green belt of Niamey. Photo: Soulé Moussa

"With limited external aid, farmers themselves have developed a range of ways to increase their resilience."

Introduction

The West African Sahel is very vulnerable to the effects of climate change, due to land degradation, dependence on rainfed farming, political instability, poor governance, food insecurity, terrorism, poor infrastructure, and limited technical capacity. This has particular impacts on the agricultural sector (Sissoko et al. 2011; Zougmoré et al. 2016).

High levels of poverty and illiteracy also challenge agriculture, alongside a lack of adequate agricultural policies and agricultural investment, and limited mechanization. Conflict also affects agricultural societies and pastoral activities (Snorek et al. 2014). In addition, there is population pressure. Niger has the world highest population growth (INS 2016), which leads to agricultural saturation, the now total absence of fallowing land and increased land-use conflicts.

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Climate change impacts on agriculture

At the national level, the government estimates the agricultural population at 15,665,750: 7,917,439 male and 7,748,311 female (Ministère de l'Agriculture du Niger 2019). Agrosilvopastoral production systems dominate, with millet and sorghum the main rainfed crops, and beans and groundnut the main cash crops (Ministère de l'Agriculture du Niger 2019). There is also some oasis agriculture (rainfed and irrigated), and limited urban and peri-urban farming and orchards. Agriculture in Niger suffers from intrinsic challenges such as low soil fertility and unsustainable agricultural practices, which are worsened by the collection of almost all crop residues for other uses and the use of fire to clear land.

In Niger, climate change has direct negative effects on agricultural production through increased variation in rainfall, recurrent droughts, flash flooding, higher temperatures and strong winds (Agrhymet 2015; République du Niger 2020), with notable impacts on millet, the main subsistence crop in the country (Ben Mohamed et al. 2002). The frequency of bush fires and incidences of crop and livestock pests and diseases are also increasing, as is the invasion of farmland and pastures by weeds (Habou et al. 2016; Ministère de l'Agriculture du Niger 2019). Indirect effects include increases in climate-related malaria and diarrheal diseases that negatively affect agricultural societies. Climate change also amplifies conflicts and migration.

Adaptation strategies and their implications

Land restoration

Nigerien famers use many different land restoration techniques to adapt to the effects of climate change on their land. A wide range of techniques are used, including *zaï* pits (*tassa* in the local Hausa language), stone bunds, half-moons, micro-dams, grass strips, filtering dykes, mulching, multiple cropping systems, crop rotations, fallows, zero tillage, agroforestry, farmer managed natural regeneration (FMNR), use of firebreaks, planting wind breaks, stabilizing sand dunes, applying manure or compost, micro-doses of chemical fertilizers, early sowing, and developing contracts with pastoralists to have their animals stay in the fields to provide additional manure (Nouhou Koutcha 2016; Oumarou 2007). The technique that the farmers choose varies according to the problems they face and the knowledge they have, but the overriding purpose of all techniques is to improve water retention and soil fertility to maintain or increase yields in response to land degradation. And adoption of some has been widespread, with *zaï* pits, half-moons and FMNR along with more intensive rice cultivation reported to have been implemented on more than 310,000 hectares in Niger (Botomi et al. 2015).

Another adaptation is planting species such as *Andropogon gayanus, Euphorbia balsamifera, Leptadenia hastata* and *Leptadenia pyrotechnica* to stabilize sand dunes. These species also have socioeconomic and food security benefits. For example, the seeds and mulch of *Andropogon gayanus* are harvested and used by farmers or sold for animal feed, and the grass from the species is harvested for use in preparing building materials. The leaves of *Leptadenia hastata* are consumed or sold for food. These species are also planted as a land restoration technique over large areas where male, female and youth farmers benefit from cash-for-work arrangements in many private and public projects. This strategy helps to reduce rural poverty and migration, as well as the risks of youth joining terrorist groups. In addition, restored lands have improved productivity and increased resilience to the uncertainties of climate change.

Cropping systems

Farmers have also developed cropping techniques to mitigate the negative effects of climate change. They practise multiple cropping systems and crop diversification to reduce climate-driven crop failure, reductions in yields and loss of soil fertility. For example, they grow cereals such as millet or sorghum with tigernut (*Cyperus esculentus*) or other crops for home consumption or sale, with nitrogen-fixing legumes such as groundnut or different varieties of beans such as cowpea (*Vigna unguiculata*). This crop diversification reduces crop failures and yield losses, which has positive impacts on nutritional, pastoral, economic and land restoration considerations and enhances farmers' resilience.

A key adaptation strategy is combining crops with livestock and forestry. This agrosilvopastoral land use enhances soil fertility, reduces poverty, and leads to biodiversity conservation, all of which further enhance resilience. The use of drought-tolerant and early maturing crop varieties is another important measure to reduce the impacts of climate shocks (Ministère de l'Agriculture du Niger 2019).

In addition, irrigation is a key adaptation strategy to boost crop production where water is available (CNEDD 2020). Examples include agricultural crops in oases in Agadez Region, and crops, mainly fodder, in interdunal depressions (*cuvettes*) in Zinder and Diffa regions. The most important irrigated cropping system is found near dams and alongside wetlands such as along the Niger River in Niamey and in Tillabéri Region (République du Niger 2020).

Non-timber forest products

Agroforestry with multipurpose tree species is a key adaptation measure. Farmers plant woody species in croplands or encourage natural regeneration. This ensures varied ecosystem services that reduce the effects of climate change on agricultural production and allows farmers to harvest non-timber forest products. The sale or home consumption of these products helps people cope with household food shortages during drought years (Lawali et al. 2018; Sendzimir et al. 2011). Farmers harvest flowers, fruit, fibres, fodder and medicines from a wide variety of trees for domestic use and for sale. Species include *Adansonia digitata, Acacia raddiana, Balanites aegyptiaca, Boscia senegalensis, Faidherbia albida, Leptadenia hastata, Maerua crassifolia, Neocarya macrophylla, Parkia biglobosa, Prosopis africana, Piliostigma reticulatum, Sclerocarya birrea, Tamarindus indica, Tapinanthus* species, *Vitellaria paradoxa* and *Ziziphus* species.

Women harvesting *Balanites aegyptiaca* flowers for human consumption in Koygolo village, Dosso. Photo: Manzo Farouk

In the wet season, farmers also harvest wild herbaceous species such as *Ceratotheca sesamoides*, *Cleome gynandra* and *Corchorus tridens* on their farmland for household food and for sale, and some store them until the dry season. Some farmers have gone so far as to domesticate some wild plants for food and commercial purposes, such as *Cassia tora* (*tafasa* in Hausa) in the department of Aguié in Maradi Region

Millet fields in the green belt of Niamey. Photo: Soulé Moussa

(Moussa et al. 2017). Farmers harvest and store cowpea tops (*takunka* in Hausa) for human consumption as a dry-season strategy (Moussa 2013); they also eat immature cowpea pods (*hansari*) in salads in the face of food insecurity in the lean period before the millet harvest is ready. Furthermore, the minor millet *Digitaria exilis* (*fonio* blanc) is also cultivated for food and for sale. In addition to plants, farmers also collect crickets, which are eaten as a protein source or sold in local markets.

Cultural adaptations

National planting programmes such as national tree-planting day on 3 August, play a crucial role in climate change adaptation related to agriculture. This encourages the planting of a range of trees species along roads, in towns and schools compounds, and in croplands. Programmes also include cultural gatherings of farmers such as national and regional agricultural fairs (e.g, *le salon de l'agriculture Sahel, la cure salée*). These gatherings support farmer exchanges, capacity building, awareness raising, and provide incentives such as prizes for farmers in various categories, including the most inspiring innovations. Such gatherings are thus important ways to strengthen the adaptive capacity of farmers. They also help to reduce conflicts between farmers and pastoralists, and promote the use of climate smart agricultural technologies.

At the local level, another adaptation strategy is the use of small-scale rainfed farming systems, specifically by youth and women. Youth farmland is usually worked in the evenings or at the close of the family cropland working period, during holidays, and on Fridays, when many do not work due to its being the Islamic day of prayer. Women's farmland is usually located within their husbands' farmlands; women generally cultivate the cash crop.

Peri-urban rainfed agriculture in Maradi. Photo: Soulé Moussa

At the national level, adaptation is supported by a number of laws that aim to build the resilience of farmers, including the rural code, pastoral law, forest law and biodiversity law, all of which help to regulate the balanced use of agricultural land and natural resources in the context of climate change and expansion of agricultural land.

Institutional and individual capacity building

Understanding the role of the many private and public institutions in Niger in enhancing farmers' climate change adaptation is critical. These organizations assist farmers with basic education in literacy and numeracy, and provide weather and climate information and technical advisory services. There is also the national 3N policy – *Nigériens Nourissent Nigériens* — which aims to reduce the effects of climate change on key sectors such as agriculture. The adaptive capacity of farmers is strengthened through workshops, village gatherings, rural radio programmes and similar initiatives, and through the provision of improved rural infrastructure (such as roads, marketplaces and storage facilities) and better access to agricultural loans and inputs such as seeds and fertilizers.

Government responses

In 2015 the government provided 8,516,435 tree seedlings for general distribution with 23,501 hectares planted, and an additional 5,937 hectares of sand dunes were fixed through planting (INS 2016). There were 164 bush fires (*fuex de brousse*) reported that year, similar to previous years, and so an additional 17,205 km of fire breaks were also prepared.

For the 2019 agricultural production season, the government — through its *Programme de la Renaissance Acte II* — distributed significant quantities of diverse agricultural inputs to farmers to help them cope with the effects of climate change. These included 5,063 tonnes of certified seeds, 12,875

Urban farming and honey production in an urban orchard in Maradi. Photo: Soulé Moussa

tonnes of fertilizer, 61,538 litres of pesticide (to treat 70,280 ha), 19,853 packets of fungicide powder, 370 chemical applicators, 49 cattle and donkey carts and 46 ploughs (Ministère de l'Agriculture du Niger 2019). The implication of such assistance from the government is that the use of agricultural inputs enhances agriculture production, reduces crop failure, restores land and reduces poverty. It indicates the importance that the government places on assisting the agricultural sector in order to support food security.

General recommendations

- Raise awareness among farmers, local leaders, civil servants, academic institution staff, the private sector and the general public of climate change and its impacts.
- Include climate change in the curricula on national universities, to ensure graduates can act as ambassadors for climate change adaptation.
- Take account of climate change adaptation strategies in agricultural policies, and develop national, regional and commune-level adaptation plans, including public finance and encouraging private investments for climate actions.
- Increase the number and coverage of weather stations for more timely and accurate forecasting.
- Construct more dams and promote water harvesting methods to increase water availability for small-scale horticulture and larger-scale irrigation of agricultural crops.
- Improve agricultural insurance services for farmers from the private and public sector to help them cope with crop failure, damage to infrastructure, loss of human life and loss of livestock from climate shocks.

- Improve access to agricultural loans, including for storage facilities for rainfed and irrigated crops to reduce post-harvest losses.
- Increase the production and distribution of more tree seedlings, and of a more diverse range of species that produce food for human consumption to improve nutritional security.
- Develop urban and peri-urban agriculture and urban forestry for food production.
- Encourage the cultivation of fodder species and improve storage to support supplies especially in the dry season.
- Promote programmes that increase the engagement of youth and women in the agricultural sector and in large-scale farming in particular.

Conclusions

Agricultural systems in the West African Sahel are vulnerable to climate change. Farmers in Niger have developed many adaptation strategies, which provide myriad services with socioeconomic and ecological benefits. These include *zai pits*, stone bunds, mulching, crop rotation, multiple cropping systems, half-moons, filtering dikes, fertilizer micro-doses, use of manure, and farmer managed natural regeneration. Strategies also include pest control measures, use of drought-tolerant and early maturing crops varieties, improved crop storage facilities, and use of timely and accurate weather forecasting. Some adaptation measures involve the use of land law and environmental law to regulate the use of resources. In addition, farmers reduce risks through loans from agricultural banks to invest in irrigation infrastructure and agricultural inputs. These measures are being considered at the highest level, such as in the national strategy and plan for climate change adaption in the agricultural sector 2020 (République du Niger 2020). Now it is hoped that these strategies can be adequately financed and effectively implemented so farmers and pastoralists alike can have the support they require to adopt more climate-smart practices and improve their livelihoods.

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The climate-smart village approach: communities at the heart of restoration in Senegal

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Training of producers in the Participatory Integrated Climate Services for Agriculture approach. Photo: Baba Ansoumana Camara

"Only the appropriation and governance of sustainable land management by local communities can regreen the Sahel"

Introduction

Land degradation affects 24% of the world's land surface and 1.5 billion of its people. It is the result of human activities, exacerbated by natural processes, and is closely linked to climate change and loss of biodiversity. In Africa two-thirds of arable land is degraded. In Senegal, 2.5 million hectares are degraded (CSE 2011); the central "groundnut basin" is particularly affected (Wezel and Lykke 2006). Increasing the capacity of smallholders to address land degradation and adapt to climate variation is paramount, which is why the Senegalese Institute for Agricultural Research (ISRA) and its partners adopted the holistic and participatory "climate-smart village" approach. Based on innovative local governance, this approach includes seven components: (1) climate forecasts and information;

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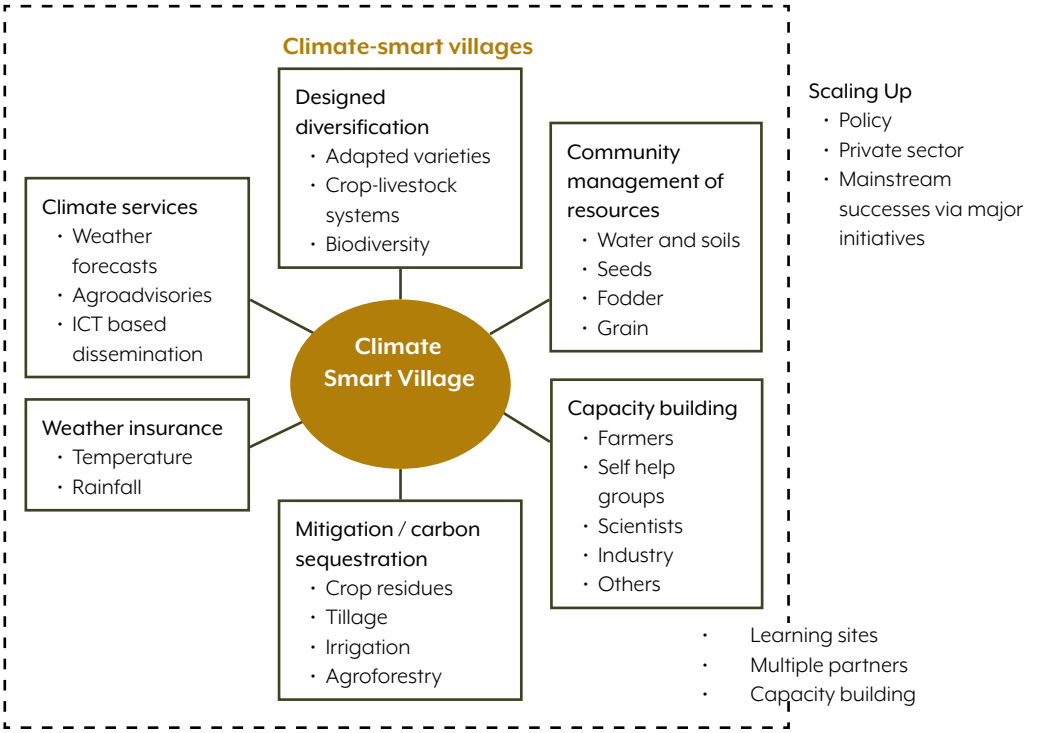
(2) resilient crop varieties and good agricultural practices; (3) agroforestry with fruit and fodder species; (4) farmer managed natural regeneration; (5) inter-village silvopastoral areas; (6) planting of native fruit trees; and (7) small forestry and farm businesses (Sanogo et al. 2019).

An integrated participatory approach beyond the fields

The climate-smart village approach promotes the participatory development of context-specific land management practices, taking into account environmental (sustainable management of resources, ecosystem resilience) and socio-economic (institutional organization, empowerment, food security) aspects. It guides the actions needed to transform agricultural systems so they effectively ensure food security and support livelihoods in a changing climate (Sanogo 2018). This requires assessing site-specific social, economic and environmental conditions to identify appropriate farming practices (Sanogo et al. 2016). The aim is to sustainably increase agricultural productivity and income, build community and ecosystem resilience, and reduce greenhouse gas emissions.

The approach was piloted in Daga Birame, Kaffrine Region. An initial assessment of existing capacities for climate change adaptation was carried out using the TOP-SECAC Toolkit (Somda et al. 2011), which included participatory mapping of livelihood and climate hazards. The next steps involved creating a vulnerability matrix to analyze community perceptions, and an adaptation strategy matrix to identify and analyze current and future adaptation strategies. The resulting measures were structured around different components (Figure 1).

Figure 1: Conceptual framework for the climate-smart village approach (Bayala et al. 2016)



An innovative platform and governance model

In applying the climate-smart village approach, an innovation platform was created as a driving force (Sanogo et al. 2017; Raile et al. 2019). This included 194 farmers (including 110 women) from all social levels of the community, plus technicians, administrative staff, elected officials, researchers and association representatives. The platform is coordinated by a committee of 17 members, including 6 women, with groups for specific purposes, such as the transformation commission for promoting non-timber forest products (especially the processing of baobab fruit and marketing of the fruit powder). There are also groups for market gardening, agroforestry, farmer managed natural regeneration, tree nurseries, and protecting inter-village silvopastoral areas.

The innovation platform is recognized as the village's decision-making body. It facilitates information exchange and sharing, and identifies and conducts capacity building for producers. It also relays climate information to farmers, and facilitates access to research results, particularly those related to improved seeds and cultivars. The innovation platform has also contributed to the development of income-generating activities and to access to finance.

Building adaptive capacity

Each year since 2014, training has been provided in the use of climate services by a multidisciplinary working group in Kaffrine. During the rainy season, climate information is sent via text messages to 11 members of the platform, who then relay it to all 194 members, allowing them to choose the best suited varieties and reduce the need to reseed. In addition, farmers believe that taking this information into account allows them to reduce weed density and the time needed to control weeds.

Smallholder farmers have also benefitted from capacity building through the participatory integrated climate services for agriculture approach, carried out by ISRA, ICRAF and the National Agency for Civil Aviation and Meteorology. This allowed 21 men and 21 women farmers from Ngouye and Daga Birame villages to plan their production and other livelihood activities through a better understanding of local climate characteristics and a joint analysis of their resources and personal circumstances (Sanogo et al. 2016; Dayamba et al. 2018). Following the training, farmers said that they now keep track of all the money they spend on production activities.

Protecting baobabs

A study trip organized as part of the 'Farms of the Future' approach allowed farmers of Daga Birame to visit Dahra commune in Linguère Department, where they saw the value of fruit trees, and found that the baobab fruit juice they were served came from their own region. On their return, they decided to plant appropriate fruit tree cultivars, and to ban the cutting and excessive pruning of baobab trees. Baobabs in Daga Birame have always been overexploited for animal and human food, which resulted in a lack of regeneration. To address this, each baobab tree in the village was marked and its use was prohibited. This has led producers to use other plant resources for livestock feed, including crop residues and cereal byproducts, yielding convincing results. As a result, communities and especially women, now have an ample supply of baobab fruit for generating income.

Training of producers in the Participatory Integrated Climate Services for Agriculture (PICSA) approach. Photo: Baba Ansoumana Camara

Inter-village silvopastoral areas

This initiative resulted from the initial assessment exercise, which identified the progressive degradation of vegetation as a major cause of increased risks from strong winds, floods, soil erosion and drought. The community of Daga Birame established participatory management over 128 hectares of communal land as inter-village silvopastoral areas, with a further 47 hectares around Katre Sy village. These areas provide fodder for local livestock and for the livestock of pastoralists who pass through, also providing additional income, and sustainable ecological, socioeconomic and cultural benefits. A committee of about ten people (men and women), officially recognized and appointed by local authorities (municipalities, Water and Forests and the Prefect), enforce the rules for managing these areas. Cultivation and wood cutting are prohibited in these areas, but grazing is permitted. The success of this approach is based on the will to act together, self-discipline, the involvement of technical partners, and the commitment of elected officials. Significant regeneration was seen after only four years (2014–17), revealing the potential of this strategy to rehabilitate degraded lands in the Sahel. Species that regenerated naturally included trees of economic and nutritional value, such as *Adansonia digitata*, *Albizia chevaleri*, *Bombax costatum*, *Cassia sieberiana*, *Cordyla pinnata*, *Detarium microcarpum*, *Diospiros mespiliformis*, *Parkia biglobosa* and *Tamarindus indica*.

Promoting agroforestry

Agroforestry was promoted by farmer field schools. The goal was to improve productivity while also producing biomass for environmental benefits and carbon sequestration. Demonstrations and trials included farmer managed natural regeneration (FMNR), good agricultural practices (mulching,

Protected baobab (*Adansonia digitata*) trees. Photo: Baba Ansoumana Camara

application of organic manure, ploughing, mineral fertilization by micro-dosing) and the use of climate forecasts and information (choice of varieties, technical management). In 2014, a rain-deficit year, this combination of climate-smart agricultural technologies reduced the amount of mineral fertilizer required by 51%, reduced the need to have to sow crops a second time, and increased production by 60%. The approach also allowed farmers to better understand how such integrated agroecosystems function. In addition, the community was made aware of FMNR, leading to a more than doubling of adopters between 2014 and 2020, from 25 to 60 smallholders. This in turn led to an increase in on-farm tree densities over 93 hectares, with a further 182 hectares now under assisted natural regeneration.

Developing value chains and diversifying incomes

Fruit trees diversify sources of food and income. Five species were identified that match local needs and context: baobab (*Adansonia digitata*), guava (*Psidium guajava*), jujube (*Ziziphus mauritiana*), soursop (*Annona muricata*) and tamarind (*Tamarindus indica*). The species also include grafted varieties of baobab, jujube and tamarind. In 2016, group members also decided to combine trees with groundnut cultivation.

Income from the sale of jujube fruit increased from an insignificant amount in 2014 to €95 in 2018, along with a gain of €390 in association with groundnut. An economic evaluation showed that domestication is a profitable practice, with a net present value (NPV) of CFA 118,078 (€191) and an internal rate of return (IRR) of 27% (Sanogo et al. 2019). In addition, an initiative in 2014 called "One woman, one fruit tree" became "One woman, one agroforestry garden." The initiative drew inspiration from

experiences acquired in demonstration plots: 22 women learned how to graft trees, and 300 fruit trees were provided for planting on their own land.

Women advocated for the protection of baobab trees in 2014. They obtained fruit for processing a year later, and took out a loan from the Daga-Birame Innovation Platform, which they later repaid. The income generated goes into savings accounts; this amounted to CFA 112,170 (€171) in 2015, CFA 192,500 (€294) in 2016 and CFA 458,000 (€699) in 2017. Women are still uncertain as to how to use the income, but have stated a desire to benefit from capacity building for managing community revenues in a way that avoids conflicts.

Impacts

Satellite images taken in 2004 and 2018 show the impacts on land use and vegetation cover from the implementation of new practices (Figure 2). As shown in Table 1, there were decreases in the area of farmland, without natural regeneration (–7.3%); village woodland (–0.5%), medium-density savannah zones (–2.4%), and bare land (–0.6%). There were increases in urban areas (+0.1%), low-density savannah zones (+0.8%), high-density savanna zones (+1.6%), and cultivated land with FMNR (+7.8%).

Overall, practices initiated a process of regeneration on 151 ha, and stabilization on 867 ha , but 150 ha (13%) of the land still faces degradation. There was a significant increase in tree density and a reappearance of wild animals such as guinea fowl, partridges, monkeys and warthogs. Areas with regeneration also led to an increase in fodder availability (from 50 to 100 carts), and in fruit production (from 10 kg to 500 kg of jujube, and from 150 kg to 3,000 kg of baobab). An economic assessment confirmed the economic viability of these newly restored areas (NPV = CFA325,612 > 0, and IRR = 33% > 8%).

Table 1: Assessment of changes in land use and tree cover in Daga Birame, 2004–2018

	Area (hectares)		% change in tree cover
	2004	2018	
Farmland without FMNR	736	634	–7.3
Farmland with FMNR	193	302	+7.8
High-density savannah zones	11	34	+1.6
Medium-density savannah zones	145	112	–2.4
Low-density savannah zones	18	29	+0.8
Managed areas	0	6	+
Village woodland	7	0	–0.5
Bare land	44	36	–0.6
Urban areas/habitations	13	15	+0.1
Water bodies	1	1	0

Results of natural regeneration. Photos: Baba Ansoumana Camara

Conclusions

The climate-smart village approach created enthusiasm and commitment from farmers in seeking solutions to the problems and constraints that they themselves identified. The approach also involved strengthening the capacity of technical staff to use new tools, and to understand and support the new methods, with complementary finance to support the changes.

However, the success of regreening actions such as these requires a combination of legal, institutional, organizational, sociocultural, economic and ecological factors. A failure to consider any of these factors will hamper progress.

The remaining challenges include the limited involvement of local elected officials in environmental and state-owned commissions, and their lack of knowledge of decentralization laws. In addition, there are issues at the organizational and sociocultural level. These include the exclusion of women, youth and pastoralists; the limited involvement of monitoring organizations; interference by religious leaders (*marabouts*), inconsistent sectoral policies, and lack of synergy between projects and programmes.

Involving local communities in the identification of problems and in the planning, implementation and governance of sustainable land management must be the basis of all interventions aimed at reversing the process of land degradation in the Sahel. Equally crucial is awareness-raising among communities and strengthening their capacity through farmer-to-farmer exchange visits, farmer field schools, and specific training that promotes wide-scale adoption of best practices. Finally, supporting restoration through the development of agroforestry resource value chains helps to empower communities and sustain interventions.

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Large-scale regreening in Niger: lessons for policy and practice

Adam Toudou, Abasse Tougiani & Chris Reij

Livestock in a high-density agroforestry parkland in southern Zinder, Niger. Photo: Chris Reij

"The creation of five million hectares of new agroforestry parklands in Niger may be the largest restorative transformation in Africa."

Introduction

By the mid-1980s, almost all the natural vegetation in densely populated areas in central Niger had disappeared, and this part of the country was characterized by near-continuous agriculture. Since that time, the need to intensify agriculture has motivated large numbers of smallholder farmers to increase the number of on-farm trees. This happened not through the planting of seedlings, but through the protection and management of woody species that resprouted naturally on smallholders' farmland. In this way, farmers contributed to a significant regeneration of new agroforestry parkland.

During a visit to Maradi Region in central Niger in 2004, it was clear that farmers had begun to protect and manage woody species

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over large areas of their farmland. This farmer managed natural regeneration (FMNR) had been actively promoted by several projects since the 1980s and had already been reported on. But surprisingly, no one had investigated the true impacts of this phenomenon. With this in mind, the authors decided to look into the scale of regeneration between 2004 and 2009, using satellite images and field visits.

During this time, it became clear that smallholder farmers in the regions of Zinder and Maradi regions and adjacent parts of Tahoua Region had protected and managed the natural regeneration of woody species on about five million hectares of farmland (Reij et al. 2009). This large-scale creation of new agroforestry parklands is most likely the greatest positive environmental transformation in Africa. Even more remarkable, it has occurred in a country that according to the Human Development Index Rankings of the UN has always been the poorest or second poorest country in the world (http://hdr.undp.org/en/content/2019-human-development-index-ranking)

Explaining the causes

Changes in rainfall and land management

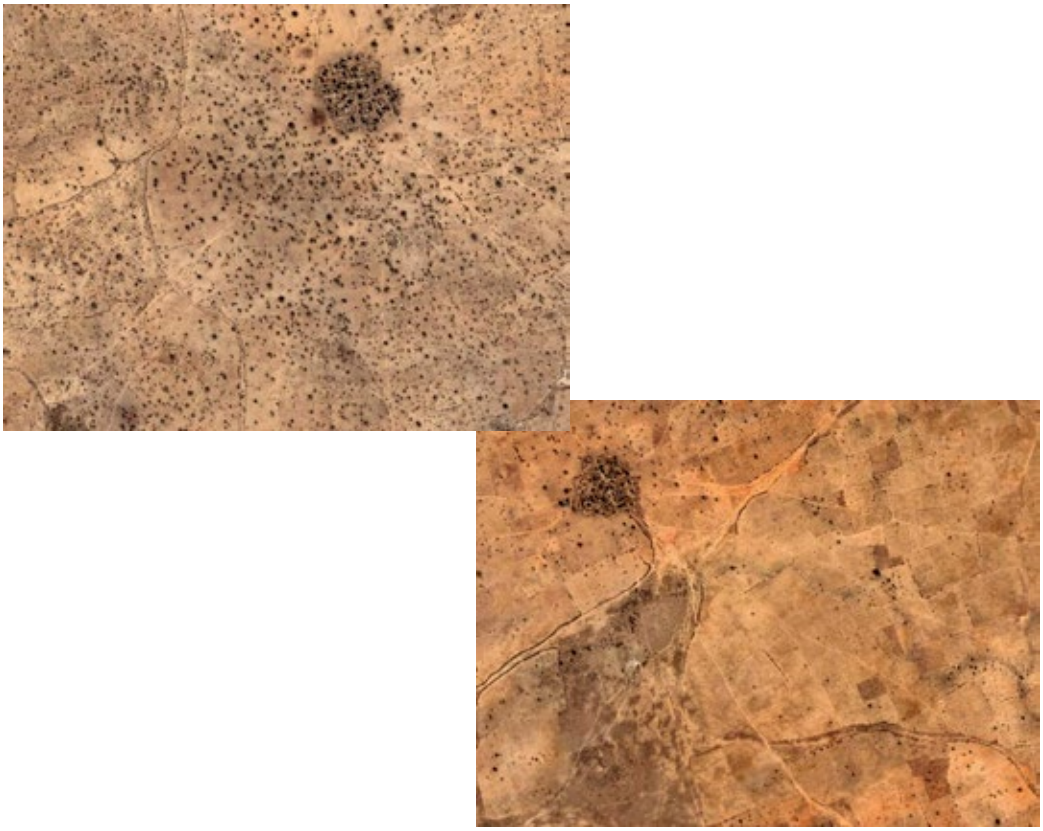
Some people argue that increases in rainfall since the late 1980s triggered a process of regreening in Niger and across the Sahel (Olsson et al. 2005; Hermann et al. 2005). This reportedly contributed to an increase in herbaceous species (mainly annuals) on sandy soils, but not necessarily to an expansion of woody vegetation cover. One thing is certain: the large-scale emergence of agroforestry parklands in central Niger is far beyond what would be expected from an increase in rainfall alone. Rainfall may have contributed to the process, but it does not explain it.

Smallholders in Maradi Region began to protect woody species regenerating on their farmland starting in the mid-1980s, a period characterized by severe drought. If rainfall were a determining factor, then northern Nigeria — with higher rainfall than southern Niger — should have had higher on-farm tree densities. However, the images below show that just across the border from Maradi and Zinder regions in Niger, the number of on-farm trees in Nigeria is much reduced. Thus, it appears that rainfall can contribute to the process of regreening, but human management is a much more significant determining factor. The key species regenerating on farms in central Niger include *Faidherbia albida*, *Piliostigma reticulatum*, *Combretum glutinosum* and *Guiera senegalensis*. Farmers perceive that these species have a positive impact on soil fertility or on producing fodder or high quality firewood.

The urgent need to intensify agriculture

It is striking that on-farm regreening in Niger occurred mainly in areas with higher population densities. In areas with few people, such as the border region between Niger and Burkina Faso, the vegetation continues to degrade. Population densities in southern Maradi and Zinder regions are >100 persons per km^2 and the large-scale regreening in these area is a story of "more people, more trees," as shown in the images on the next page.

Prior to 1985, standard farming practice involved clearing all bushes and cutting back regenerating trees and shrubs on cropland at the onset of the rainy season. The number of on-farm trees had declined to an all-time low, which meant that farmland was largely barren and exposed to the wind and sun. Women had to walk an average of 2.5 hours each day to collect firewood, and given its scarcity, the use of crop residues and manure as a source of domestic energy was common. Unsurprisingly,



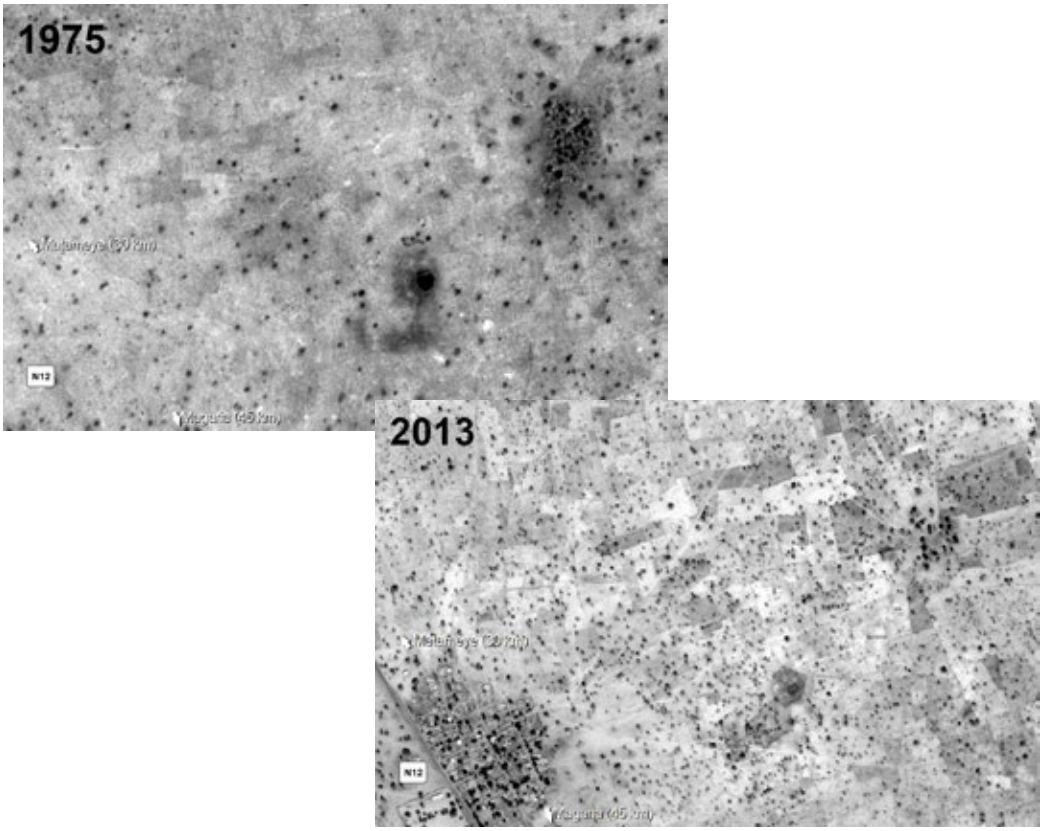
Left: A village in southern Niger (Maradi Region) close to the border with Nigeria. Right: a village in northern Nigeria close to the border with Niger. Population densities and soils are similar, but the number of on-farm trees in northern Nigeria is significantly lower than in southern Niger. Photos: Gray Tappan

crop yields were low and declining soil fertility was a main concern of farmers. Yamba and Sambo (2012) found that 58% of 70 household heads interviewed in Kantche district, Zinder Region, mentioned improving soil fertility as the main reason to increase on-farm trees.

Low costs and quick benefits

Protecting and managing naturally regenerating woody species is a low-cost technique, requiring only some labour for their protection, thinning and pruning. This process becomes easier still if farmers organize themselves at the village level and adopt bylaws for protecting and managing their new tree capital. This means that FMNR is not only a technique, which can easily be mastered by all land users, but also contributes to developing village institutions, which is a more complex and time-consuming process.

The common understanding is that when you plant a tree, the benefits will accrue for the next generation. However, in the West African Sahel, the natural regeneration of woody species produces benefits more quickly than that. By the first or second year emerging stems have to be thinned and



Left: A village in southern Zinder Region in 1975: on farm tree densities are low and the village is small. Right: The same village 38 years later: on-farm tree densities have increased. The village that existed in 1975 is smaller, but a new village has been built along the road. Source: CILSS (2016)

pruned, yielding twigs and small branches for use as firewood and leaves for fodder or to enrich the soil. As soon as smallholder farmers observed this happening on the fields of fellow farmers, many hundreds of thousands of them in the Maradi and Zinder regions quickly adopted FMNR, and most did so spontaneously.

Another benefit of increasing on-farm tree numbers is that farmers created more complex and productive farming systems that are also more resilient to drought. In the 1980s, farmers often had to sow their crops several times after they were destroyed by strong winds, which covered the crops with sand. When farmers increased the number of woody species on their land, they only had to sow a crop once as the vegetation helped block the wind. More woody species also meant more fodder production, so farmers could keep more livestock. An indication of increased resilience in Kantche District, with a high population density and high on-farm tree density, is that farmers produced a grain surplus of almost 14,000 tonnes in 2011. This was a year of serious drought, when the national grain shortage was estimated to be around 500,000 tonnes.

A young and dense agroforestry parkland dominated by *Faidherbia albida* in Niger's Zinder region after the harvest. Two piles of crop residues can be seen between the trees. Photo: Chris Reij

The start and spread of FMNR

Several stories exist about how FMNR started. One is that Australian agronomist Tony Rinaudo, who since 1980 had tried in vain to plant trees in Maradi, discovered some green stems in a sandy field in 1983, emerging from stumps hidden just below the surface. His conclusion was that there was an "underground forest" of such living stumps that had been cut in the past but never allowed to resprout. The Maradi Integrated Development Project then offered food aid to farmers willing to protect the stems regenerating from these tree stumps in 1984 and 1985. These being drought years, thousands of farmers were willing to do so. A normal harvest followed in 1986, so food aid was discontinued; at least half the farmers again cut the young trees that they had protected, but others continued to protect them. Those who had cut their young trees quickly regretted it when they saw the positive impact on crops in the fields of those farmers who had continued to protect and manage the regenerating trees. Many famers then quickly started all over again to protect the trees without any external incentive (Dieterich 2018).

A second story comes from Dan Saga village in Aguié district, Maradi Region. Several young farmers who had left as labour migrants to Nigeria returned too late in the season to clear trees and shrubs from their fields before sowing crops. During harvest time, these smallholders observed that their yields were higher than those of fellow farmers who had simply cleared their fields "as usual." The same thing happened the following year, and that really convinced their neighbours that it made good sense to increase the number of woody species in their fields (Pye-Smith 2013).

Villages in Maradi region have organized rural firewood markets based on the sustainable management of new agroforestry parklands. Photo: Chris Reij

Changing perceptions of ownership of on-farm trees

Before 1985, the common view was that all trees belonged to the government. This was a legacy from the colonial period and was reflected in the country's 1974 Forest Code. But since the late 1980s, farmers began to perceive that they had a right to the trees on their own farms, a change that was catalysed by a national debate in 1984 about how to fight desertification. This perception led to increased participation by local communities in the management of their natural resources. This *de facto* ownership of trees did not mean, however, that farmers could freely manage or cut their on-farm trees as they pleased. They still required a permit from the forestry service to harvest "their" trees, or even to prune them. However, the 2004 Forestry Code enshrined the acknowledged rights of communities to their own trees, which they could manage and exploit with the approval and technical support of the forestry service.

The role of government

Forest service staff in Maradi and Zinder regions cooperated with regreening projects, and began supporting FMNR at an early stage, although it took longer for senior national-level forestry agents to perceive its importance. For many years, their focus continued to be on tree planting. The past decade, however, has seen an increasing awareness at all levels of government about the importance of FMNR, and about the massive scale of the transformation in central Niger. From technical agents at the local level to regional governors, the Minister of Environment and even Niger's President, they are all aware of FMNR and its impacts, and they all now actively support it. A recent development is that on 30 July 2020, the President of Niger signed an implementing decree regarding FMNR that fully

recognizes the rights of farmers to their on-farm trees and allows them to manage their woody species (thinning, pruning) without fear of being fined by forestry agents.

The role of researchers

A number of researchers from the National Institute for Agronomic Research of Niger (INRAN) and the University of Niamey have accompanied the process since the late 1990s. They became actively involved in supporting an IFAD-funded project in Aguié District, Maradi Region, which promoted FMNR and supported the building of village institutions. These researchers have since undertaken and supported a growing number of studies by masters and PhD students, producing increasingly convincing evidence of the multiple positive impacts of FMNR.

Lessons for policy and practice

Identify and analyse regreening successes
Small and large regreening successes can be found in every country, and can be used as sources of information and learning. More systematic efforts can also be organized to take stock of transformative changes and notable successes in restoring degraded landscapes, and to improve understanding of key enabling factors, positive impacts and significant outcomes. This kind of stocktaking is rarely undertaken, but the increased availability of high-resolution remote sensing data, time-series analysis of imagery can help to quantify the extent and impacts of regreening. More attention should also be given to analysing the cost-effectiveness of improved practices such as FMNR, and to the associated changes in crop yields, food security, poverty reduction, household resilience, water supplies, carbon stocks and other factors.

Develop a communication strategy
It is important to share information about existing successes as widely as possible in rural and urban areas to accelerate the adoption of FMNR as farmers listen to farmers working under similar conditions. This can be achieved through newspaper articles, television documentaries and radio programmes, where land users (men and women) can share their regreening experiences.

Mobilize and organize smallholders
Getting the right information to farmers about what works and why in land restoration is especially important. This information transfer can be accelerated by organizing farmer-to-farmer study visits to increase exposure to what those in other areas have already achieved. Working with farmer groups helps to increase participation and stimulate community-based actions that support the protection and management of woody species. Since 1986, farmers in central Niger have not received food aid or cash-for-work for tree protection and management. The multiple benefits they have observed provide sufficient motivation for them to invest their time and energy. Also, most villages have development committees that can help encourage the widespread adoption of FMNR and other improved practice. Restoring land successfully depends largely on putting responsibilities in the hands of land users and their communities.

Strengthen village institutions
It takes time to strengthen village institutions so they can effectively manage natural resources, including trees. But in most countries, it is left to each village to develop its own bylaws, which means that most will need to spend time learning how to do this. Thus, informing villages about what has worked

and where will help, and it would be useful to propose one or more models for sets of bylaws, which can be adapted by villages to their specific situations.

Strengthen smallholder capacities

It helps to give villagers some training in best practices for protection, thinning and pruning. If done effectively, this can rapidly produce increased benefits. Smallholders with these skills and experience can then organize themselves to provide peer-to-peer training for other farmers.

Create enabling policies and legislation

Governments have a vital role to play in developing enabling agricultural and forestry policies that will induce millions of smallholders to protect and manage trees on-farm and even off-farm. At present, agricultural development policies often ignore on-farm trees, and forestry policies tend to focus on planting trees, which can cost US$500–1,000 per hectare. The implementing decree regarding FMNR in Niger mentioned above is an example of enabling legislation. When farmers perceive that they have a clear right to their on-farm woody species, they will invest in them.

Conclusions

Unless countries can manage to mobilize millions of land users to invest their scarce resources in protecting regenerating trees, the battle against land degradation cannot be won. These experiences from Niger show that hundreds of thousands of smallholder farm families have substantially increased tree cover on their farm land by investing in the management of on-farm trees. This has improved their production systems and their livelihoods. There is no reason to believe that similar success cannot be achieved in many more countries throughout African drylands and sub-humid area. The goal is to restore millions more hectares of degraded land by means of productive and resilient farming systems.

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Private sector and project initiatives

Photo, previous page: John Akulungu and his partner watering in their nursery in Upper East Region in Ghana. Using quality seeds, they produce tree seedlings in commercial quantities for sale to farmers. Photo: Jason Amoo/ World Vision Ghana.

Using market incentives to drive regreening: the case of Sahara Sahel Foods in Niger

Josef Garvi & Renate D. Garvi-Bode

Sahara Sahel Foods presenting various products at a provincial forum for local economic development policies. Photo: Sahara Sahel Foods

"This innovative business provides much-needed income for rural women and men while promoting regreening and dryland restoration."

Introduction

In Niger, since the droughts of the 1970s and 1980s, one of the most successful land restoration strategies has been the regeneration of native trees in farmers' fields. This has led to a reduction in soil erosion and an improvement in soil fertility (Garvi 2001; Birch et al. 2016). But the focus has often been on the positive effects of trees on annual crop yields, missing the other direct benefits that trees provide. The most valuable of these benefits is the potential contribution of trees as food sources, which is also a historic use that had largely been forgotten. Wild food trees are productive as well as resilient to drought and very nutritious. Readopting their consumption on a large scale could be game-changing to the Sahel: it would catalyze their propagation, bring better food security and nutrition, counter desertification, sequester carbon and sustain biodiversity. The founders of Sahara Sahel Foods felt that in order

Josef Garvi, Executive director and co-founder, Sahara Sahel Foods, Zinder, Niger and **Renate D. Garvi-Bode**, Co-founder, Sahara Sahel Foods, Ridderkerk, the Netherlands.

to bring forth such a revolution, an inclusive food processing industry should be created to serve as a stable outlet for produce harvested by rural communities from their surviving and regenerating trees.

A new life for ancient stigmatized foods

Sahara Sahel Foods was created on the assumption that the more people's livelihoods depend on the use of well-managed indigenous trees, the more they will care for them and propagate them. Experiences in direct seeding and natural regeneration showed that the main challenges to scaling up regreening were not technical but social. People didn't want more trees than what they saw a use for, and they didn't see a need for native food trees, because their focus was mainly on producing subsistence cereal crops. This was especially true for men, who were the decision-makers regarding what to grow in the fields, whereas women tended to show a greater interest in keeping these age-old food plants.

Compounding the problem was a cultural stigmatization that had taken place, fuelled by the cultural influences of arabisation and westernisation. Over the course of the past two centuries, once cherished tree foods had gradually been relegated to famine foods and their consumption was seen as a sign of extreme misery. National policies, international relief agencies and news channels considered the consumption of protein-rich products such as hanza (*Boscia senegalensis*) seeds and jiga (*Maerua crassifolia*) leaves as indicators of famine, while the vitamin-rich fruit of the native jujubes (*Ziziphus* spp.) was being sidelined by experts who promoted grafted Indian varieties instead. Could such foods ever be brought back to importance in a modern world, or were they just nostalgic memories of a fading, primitive past?

Sahara Sahel Foods argued that these foods were not losing out because of their poor flavour or other negative qualities. Scientific studies showed they had impressive nutritional value, and when properly processed they had pleasant tastes. What was getting lost was the knowledge of how to use them properly; in addition, they were penalized by the time, firewood and water needed to prepare them, and by the cultural biases. Industrial, imported foods were taking over Sahelian urban markets because they were clean, accessible and easy to cook. What tree foods needed was the means to be processed by small- or medium-sized industries, coupled with modernization and innovation.

Establishing a novel food industry

Sahara Sahel Foods was established in 2014 in the provincial capital of Zinder, Niger, in a region that its founders were attached to and where they were highly familiar with both the flora and its people. Drawbacks were the low local purchasing power and the lack of an enterprising culture; there were only three officially recognized industries in spite of Zinder Region being the most populous in the country. The company aimed to serve as a stable outlet for surplus tree produce from smallholders and for making products that people found technically challenging to prepare. Sahara Sahel Foods would source from farmers and nomads, especially women, and process foods that could be attractive to urban West African consumers.

A combination of traditional and novel products was developed from 21 native species, including pseudo-cereals, oils, drinks, nuts, sauce leaves, fruit powders, pastry, spices and jams (Table 1). There are currently about 60 products being manufactured, with more planned. The products were generally met with scepticism at first, which meant the company could not find retail partners. Instead,

it opened its own shop, which became a meeting point for customers and potential partners, with news spreading by word of mouth and social media postings. The company also participated in industry expos; six of its products won awards this way, including the Prime Minister's prize in 2017, 2018 and 2019 at the biggest annual trade show, SAHEL Niger. This testifies to the destigmatization taking place, which accelerated the acceptance of these tree foods. Top-class restaurants introduced them on their menus, and an ice cream producer uses them for one-third of the flavours in its product range. International NGOs also now recognize them, and national academics are studying these plants for their food potential more intensively than before.

Table 1: Wild food plants used by Sahara Sahel Foods

Species	Drinks	Oil	Pseudo-cereal	Fruit powder	Pastries/ sweets	Nuts	Edible leaves	Spices	Jam
Adansonia digitata	√	√		√			√		√
Balanites aegyptiaca	√	√	√		√	√			
Borassus aethiopum	√								
Boscia senegalensis	√		√		√	√			
Citrullus colocynthis		√							
Cordia nervillii	√								
Diospyros mespiliformis	√								√
Detarium microcarpum				√					
Grewia bicolor	√								
Grewia villosa	√								
Hyphaene thebaica	√			√					
Lannea microcarpa	√	√				√			
Maerua crassifolia							√		
Neocarya macrophylla		√		√		√			
Parkia biglobosa				√					
Sclerocarya birrea	√	√			√	√	√		√
Salvadora persica					√			√	
Tamarindus indica	√								
Vitex doniana	√								
Ziziphus mauritiana	√	√		√	√	√			
Ziziphus spina-christi	√	√		√		√			

Early years and lessons learned

Organizing a network of suppliers was slow at first, impeded by minimal financial resources and security issues that greatly limited the possibilities for field visits. In 2012, trustworthy villagers were approached — typically teachers, traditional chiefs, mayors or others of high social standing — who could relay information, help groups to produce shipments, and distribute payments. But this was

Delivery of produce using a local bush taxi. Photo: Sahara Sahel Foods

a complete failure, with hardly any results and vanishing cash advances. Where traders acted as intermediaries, they applied constant pressure on both sides of the value chain to get the lion's share of profits; quality was often substandard; there was no opportunity to convey environment-related messages to producers; and some traders would simply cheat people.

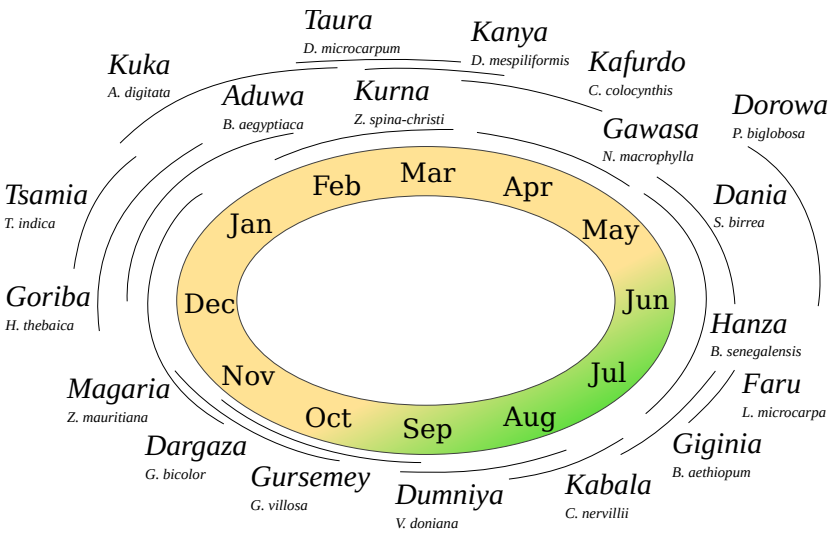
In 2013, the company recruited a dedicated community agent, who visited communities on a motorbike, sourcing produce and arranging transport to Zinder using local bush taxis and ox carts. He was first met with disbelief; people did not think there could be any market for such foods outside the village itself. They were also wary of investing efforts in harvesting produce only to see Sahara Sahel Foods fail on its promises. Initially the agent bought whatever small quantities people had in their homes and from children who collected fruits in exchange for some coins. There were no community structures to build on, but he advised them to pool their produce with neighbours to minimize transport costs to Zinder the following year. The target was 25 tonnes, but only 9 tonnes was obtained after five months of intensive scouting. This, however, was enough to convince communities that the market was real.

In March 2014, well before harvest time, people in the communities started calling the company, asking how soon they could deliver produce. The target was again set at 25 tonnes, but Sahara Sahel Foods became overwhelmed and ended up with 56 tonnes, so quotas had to be imposed on suppliers and restrictions made on new communities that could join.

Winning over smallholder families

Interest from the network of suppliers has remained strong. They currently number about 1,500 people, overwhelmingly women, from 70 villages spread over an area of more than 80,000 km². As the number of species used has expanded, several groups are now active for most of the year, since each species has a different harvest season (Figure 1).

Figure 1: Harvest seasons for the fruits from different tree species (with local names)



Communities now pressure the company to increase their quotas, with suspicion among suppliers that other groups may be obtaining larger quotas. There is a need both 1) to increase the volume sourced and processed, which is currently limited by the capacity to process and to sell; and 2) to create clear rules for quota distribution that all suppliers consider equitable, and that reward those who are diligent and quality-minded and penalize those who try to cheat. It is also necessary to fine-tune the system to promote good environmental practices and reduce exploitation by intermediaries.

Ideally, since environmental regeneration is one of the two fundamental goals of this activity, the company should follow the effects on regreening efforts very closely, but this is limited by a lack of dedicated finance. Nonetheless, the company regularly trains producers in regreening strategies, direct seeding techniques and potential uses of wild tree foods in cooperation with another enterprise, Rewild.Earth. A survey of three villages in Zinder Region showed that 95% of suppliers are protecting trees and 30% are actively propagating them (Moussa Maman 2019). The latter is remarkable, as local culture traditionally held that planting trees was God's domain and could not be done by people.

Sahara Sahel Foods initially targeted women as suppliers, but interest from men is also growing. This creates a dilemma, as men are typically the land owners and thus exert more control over the regreening of their fields. The tree food business has already empowered many women, who had very few opportunities for economic activities. It was normal for women to be the main harvesters of wild tree produce, a tradition dating back to hunter-gatherer societies. Now, as these crops grow

Debittering hanza seeds. Photo: Sahara Sahel Foods

in importance, they are becoming an interesting alternative to cereal crops, which are the natural domain of men in Nigerien society. Enrolling networks of men or encouraging their integration in large numbers into women's groups carries risks of marginalizing women again and rolling back the social progress that has been made. The ideal would be if a team spirit could emerge across the gender barrier, for productive cooperation within families and communities, that would let the women retain their well-deserved respect and position as pioneers of this trade.

In total, the enterprise purchases some 80 tonnes of produce yearly, injecting €18,000 into the rural communities this way and which represents 47% of the company's food sales revenue. Income varies widely from one community to another, however, depending on the species being harvested, their abundance, relative demand at Sahara Sahel Foods, and the industriousness of collectors. Some women earn only a few euros per year, which they use for pressing family needs; others earn hundreds of euros annually, enough to purchase livestock, land or materials for building or for expanding their homes. In addition, the factory in Zinder has 21 permanent staff (10 men and 11 women), and 300–400 temporary workers (all women) who crack nuts on a seasonal basis.

Overcoming challenges

Company profitability

Achieving profitability was the main difficulty. Since it was established, Sahara Sahel Foods has benefitted from a regular subsidy from a donor with unusual qualities, including an appreciation for groundbreaking ideas, an understanding of the hurdles that bureaucracy can create, flexibility, and crucially, the importance of long-term commitment to achieve lasting change. Since 2015, Sahara Sahel Foods' sales has grown by an average of 43% per year, and in the first quarter of 2020 it generated 46% of its

Training in the village of Rigal Saude in tree establishment techniques. Photo: Sahara Sahel Foods

revenue from its own sales. At the current rate of development, the company should become financially independent in four to five years.

Marketing

This could be done better and faster without financial constraints. Interest in adopting these novel foods is higher in the more cosmopolitan capital city of Niamey, where these rediscovered foods have quickly been considered fashionable, as opposed to the more conservative Zinder, where their reputation changes more slowly. Higher purchasing power in Niamey means that it would be a lucrative market to develop, but logistical difficulties and the lack of distribution companies for local products mean that most efforts are concentrated in the local region. The few specialty stores for local and organic foods sell more of the company's products than the supermarkets do, and setting up more such shops would have a quick impact. Most customers give great importance to health benefits. Scientific studies in this area need to be multiplied, to promote such products with confidence while avoiding "snake oil"-style sales pitches. Finally, connecting to local traditions is key. At first, promotion by outsiders was valuable in breaking stigmas surrounding these foods, but in the long term, connecting the products to their authenticity within Nigerien history has overtaken this in importance. Now, young people feel pride when they hear how these rediscovered foods were part of their ancestors' culture, and older people may still have vivid personal memories of them.

National policies

National regulations are not always well suited to the emergence of innovative, small-scale industries, and they need to be reviewed. They reflect to a large extent the heritage of old colonial economies, which focused on exporting raw materials and running large, state-controlled and well-established industries, while importing consumer foods for urban elites. The customs system is bureaucratic and

expensive for small quantities, and free trade agreements with neighbouring countries (e.g., with Nigeria) do not always function well. In addition, the tax burden is high and double taxation is common due to cumbersome administrative procedures. Making documents or skilled human resources available to help explain the fine details of regulations, and providing access for start-ups to low-cost expertise to advise how enterprises can function effectively in real life while respecting regulations would also be of value. Providing tax incentives for enterprises whose activities reinforce regreening would be helpful as well.

Financing

Experiences from Sahara Sahel Foods show that it is possible to fund such an initiative. Openness among funders is also growing, driven by the mainstreaming of social enterprises with less polarized views on the worlds of business vs. charity. Added to this are growing concerns around the global climate and biodiversity crises, and the scarcity of economic options that include rural smallholders in drylands. To stimulate similar initiatives, social seed funding will still be needed, since returns on investment may be too slow for many investors, and a strong focus on profit can dilute environmental stewardship and social inclusiveness. To avoid developing donor dependency, seed funding could be channelled as sales subsidies, where values per unit sold would decrease gradually as volumes grow, until the subsidies can be suspended. This has the advantage of stimulating the growth of a business approach without distorting the market. The approach could also be adjusted on a per-species basis to give greater support to novel foods that require longer routes to mass markets or that have greater need of conservation and propagation. This could be accompanied by support for public campaigns to promote the consumption of native tree foods, recognizing their environmental, social and health benefits. Finally, providing financial support to enterprises that develop new products or processing tools and techniques would also be very valuable.

Conclusions

The company has come a long way in showing that a social enterprise can be used to create acceptance for stigmatized foods and build markets that channel resources from urban centres to remote rural areas. It has created opportunities for some of the poorest people on the planet, living in a very harsh environment, and has proved to be a catalyst for regreening and biodiversity protection. And it has generated employment for a combination of low- and higher-skilled workers within the processing industry. It also shows that wild plants can be used for making high-quality foods without the need for so-called crop improvement programmes. There are still challenges to be met, the most crucial being to achieve financial sustainability, but the example of Sahara Sahel Foods shows that this novel idea can change the rules of food production in the Sahel.

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Financial incentives promoting afforestation in Uganda's drylands

Zainabu Kakungulu & Leonidas Hitimana

Forest related enterprises such as tree nurseries are a source of employment especially to women and youth, contributing to improved livelihoods. Photo: FAO

"Encouraging farmers to plant trees supports the restoration of degraded landscapes."

Introduction

Forests play an important role in economic, ecological and social development. They provide a wide range of products and ecosystem services, are home to many native species, and make a critical contribution to climate change mitigation. In Uganda, according to the Forest Investment Program (MWE 2017), the total economic value of forests to the national economy is estimated at more than US$160 million per year, or 5.2% of GDP, with the indirect benefits of forests through watershed protection and carbon sequestration valued at US$16 million and US$15 million per year, respectively.

Uganda's forests are threatened by increasing pressure from the growth of commercial and subsistence agriculture; unsustainable harvesting of firewood, charcoal and timber; and expansion of human settlements. The country's forest estate shrank from 4.9

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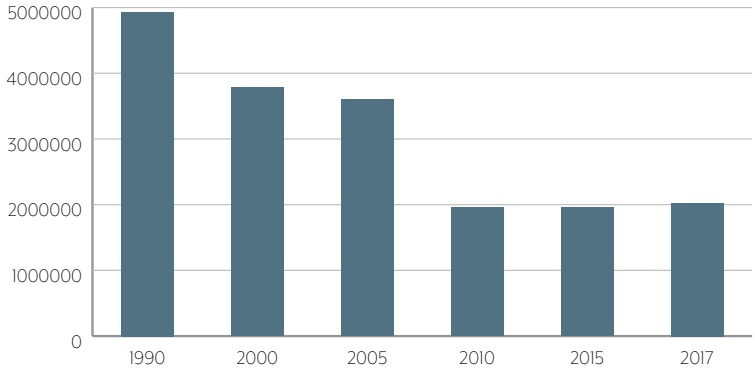
million hectares (24% of the country's land cover) in 1990 to 1.9 million ha (9%) in 2015 — a loss of three million ha in 25 years (Figure 1). This deforestation and forest degradation has resulted in a loss of biodiversity, affecting the ecological resilience of landscapes and their ability to provide ecosystem services. The latest data available from the National Forestry Authority (NFA), however, indicate a levelling off of forest loss since 2010, and even a slight increase in forest cover in 2017.

Figure 1: Forest cover change in Uganda (hectares), 1990–2017



Source: NFA (2019)

Impact of deforestation and forest degradation

Uganda's drylands cover only a relatively small part of the country, mostly in the north, dominated by pastoral rangelands. The northeastern arm of the drylands, in Karamoja Region, is the driest part of the country, with an annual rainfall of 400–700 mm (MWE 2016). Karamoja's population is highly dependent on subsistence agriculture and pastoralism; these main livelihood activities also have social and cultural significance. But as a result of this dependence on livestock rearing and rainfed crop cultivation — which are two of the most vulnerable sectors to the impacts of climate change — the region suffers chronic food insecurity. This is due to the combined impacts of high levels of poverty, low human development, unfavourable climatic conditions, and changes in temperature and rainfall over a 35-year period (Chaplin et al. 2017). The erratic weather means that farmers are less able to depend on historic weather patterns, which leaves them increasingly vulnerable to food security and climate shocks such as droughts and floods.

Globally, there have been significant efforts to promote dryland afforestation, although with mixed results (FAO 2015). There is, however, growing evidence that when planned and managed appropriately, dryland afforestation initiatives can deliver positive results. Participatory approaches in planning and implementation, empowering local communities through capacity building and supporting them to secure land-use rights are seen as key ways to enhance local ownership of afforestation projects, which is important for their success.

Use of incentives in promoting investment in afforestation

The extent to which local communities perceive the potential financial benefits from afforestation is an essential factor in the success of such programmes. Basing such initiatives on the assumption that conservation can motivate rural communities to plant trees, because environmental degradation threatens their existence, has often yielded limited results. The most important motivation for tree

Technical support is important to provide guidance to farmers on how best to manage their forest plantations, such as here, where a FAO staff members demonstrates how to measure a tree's diameter to a forest manager. Photo: FAO

planting by rural communities and individuals is an expected financial return. Forestry investment in drylands is however constrained by the slow growth of trees due to soil and climatic factors, the comparatively low opportunity cost of land, and limited income-generating options.

Often, commercial forestry is not perceived as a feasible investment because of the relatively long payback period. Unless the public sector leverages private finance, for small producers in particular, commercial forestry is not sustained. Nevertheless, a range of indirect incentives are available to policy makers to promote such investments. Enabling measures, such as institutional changes, along with variable incentives such as those related to input and output prices, can increase the profitability of an enterprise (Mortimore 2004). Cash grants and concessionary loans have proven effective in more developed countries, including interest-free loans, government grants, long-term low-interest loans, direct subsidies, and low-interest and export credit loan subsidies. However, a significant challenge with incentive initiatives that are mainly financed by public funds is their long-term sustainability.

The Sawlog Production Grant Scheme

The Sawlog Production Grant Scheme (SPGS) project was conceived within the broader government policy framework of promoting sustainable forest management through a combination of public protection and investment in private forests. In 2002, the Government of Uganda secured €12 million from the European Union to implement the Forest Resource Management and Conservation Programme, of which €1.92 million was to pilot the country's first private-sector forestry funding initiative: the Sawlog Production Grant Scheme, implemented by the Food and Agriculture Organization

of the United Nations (FAO). The aim was to support private-sector investment in establishing timber plantations to help bridge the gap in national wood supply that was putting increasing pressure on native natural forests.

This pilot phase was highly successful; more than 10,000 ha were planted, including demonstration plantations in strategic areas to raise awareness of plantation forestry. Following these initial successes, the EU funded two additional phases. Now in its third phase of implementation, SPGS has supported the establishment of more than 70,000 ha of plantations by farmers and large private-sector entities as well as communities and institutions for the commercial production of timber, poles and fuelwood. The plantations are located throughout the country, including in drylands, where several tree-planting interventions have in the past had limited success.

The difference between SPGS and previous efforts that used environmental protection as their primary objective is that there is a perceived financial benefit from participating in tree planting —a grant payment — in addition to future financial returns from timber sales. A supportive policy and legal framework, through the government's policy on leasing public degraded forest land to private developers and community groups, promotes private-sector involvement in forest management. This was a key factor in the success of the SPGS project because it addressed the lack of access to land that creates a barrier to extensive afforestation.

How the SPGS model works

The scheme has three principal components: financial support, inputs/planting materials, and technical support.

Financial support: Beneficiaries are paid an estimated US$250 per ha planted for smallholders and medium-scale farmers (up to 500 ha), and US$160 for larger companies (up to 3,000 ha), to partly cover initial investment costs, which are estimated at US$720 for the first two years. The grant is based on the principle of co-investment; i.e., beneficiaries must have their own funds and be willing to invest. The higher grant for small- and medium-scale landholders is aimed at encouraging more participation by this category of beneficiaries. Payment is made on verification of planted trees and ensuring of compliance with minimum plantation establishment standards.

Inputs/planting material: This component is targeted to smallholders with between 0.2 ha and 5 ha, and with limited ability to invest financially in forestry. Beneficiaries are provided with tree seedlings or cuttings, which constitute a large proportion of the cost of plantation establishment. In Uganda, the cost of improved seed, particularly for exotic species, is relatively high because they are not produced in country and have to be purchased from international commercial sellers. For example, a single kilogram of *Pinus caribaea* seed can cost as much as US$1,300. Beneficiaries are further supported by extensive training to improve their technical skills in forest management.

Technical support to service providers: This support targets capacity building for service providers in the forestry plantation industry. In particular, the scheme includes a programme for developing and promoting forestry contractors and tree nursery operators. Through a voluntary certification scheme, service providers are audited annually by the project and issued a certificate if they are in compliance. The checklist for auditing a tree nursery operator includes compliance with use of improved seed, minimum health and safety standards for workers, and the health and vigour of planting material.

Tree farmers are encouraged to buy their seedlings only from certified tree nurseries as a way of ensuring high-quality planting material.

Promoting afforestation in Uganda's drylands

One of the shortcomings of the first and second phases of SPGS was that no specific attention was paid to promoting forestry in drier parts of the country, despite their being the areas most severely affected by climate change. During the third and current phase, an action was instituted to encourage farmers in Karamoja to participate in tree planting (see Box). Among the key interventions to achieve this, the first was a quota system during beneficiary selection, with 600 ha allocated to Karamoja. In addition, there was a campaign to promote afforestation in the region, raising awareness through mass media, targeted training courses, and establishing demonstration and learning sites to show good practices. Capacity building was further supported through the certification of service providers such as tree nursery managers to ensure the production of quality planting material.

One challenge to forest investment in Karamoja is that the most commonly grown commercial tree species in Uganda, notably *Eucalyptus grandis* and *Pinus caribaea*, do not grow well in most parts of the region, with the exception of limited areas that have better rainfall and environmental conditions. This constrains investment in dryland afforestation. To address this, the project supports research in dryland silviculture, working closely with the National Forestry Resources Research Institute. Research trials for dryland species — including *Melia volkensii*, *Gmelina arborea*, *Terminalia brownie* and drought-resistant eucalyptus clones — have been established. The preliminary results indicate that the use of adapted tree species can be scaled up in future dryland restoration programmes.

An experience from Karamoja

Jacob Elisha Ongom is a 72-year-old retired teacher. With support from the third phase of the SPGS project, he ventured into tree planting in 2018. "When I started out, many in my family and community questioned why, at my age, I would be interested in a long-term venture like tree planting, especially as our semi-arid land is not seen as supporting tree planting. I chose to wear an entrepreneur's hat because we take risks, and today, cynics are in awe that my investment is thriving. My forest plantation investment will not only meet my future needs but also those of my children and grandchildren. Since I had no prior knowledge or experience in tree growing, much of my learning has been on the job, boosted by training, technical advice and field visits." Jacob owns a 5.6-ha eucalyptus plantation, which has also created jobs for some youth in maintenance activities such as weeding and preparing fire breaks.

Jacob Elisha Ongom (right) in his two-year-old eucalyptus plantation. Photo: FAO/ Peter Ssekiranda

A happy farmer proudly shows off her six-month old eucalyptus forest planted with support from FAO.
Photo: FAO/ Ivan Arinaitwe

Impacts

The FAO-SPGS project has supported the afforestation of more than 70,000 hectares with timber plantations, and has distributed more than 10 million seedlings to local communities over a 15-year period, at a cost of some €36 million in total, including the pilot phase. Due to a lack of formal records of the extent of the national commercial forestry estate, the figures above are based on unpublished reports, desk studies and field assessments. Recent reports on changes in forest cover (Figure 1) point to an increase in forest cover, which is attributed to tree planting, especially by the private sector and communities. In addition, rural employment opportunities have improved, both within the forests and in the support services that commercial forestry attracts. An evaluation of the commercial forestry industry in Uganda estimated that up to 12,000 jobs had been created in the upstream value chain by 2014, including in plantation establishment; and the number of jobs was expected to increase exponentially with the development of downstream processing. The most significant impact, however, is probably the increased level of confidence of the private sector to invest in plantation development. Through their umbrella body, the Uganda Timber Growers Association, private forestry investors are continuously advocating for improving investment in the country.

Lessons learned

Incentives to stimulate forestry investment

From a financial perspective, restoration projects often have high up-front costs and long timelines before reaching profitability. Using public and non-profit finance for the first few years can therefore help them obtain traditional private-sector investment and become more competitive in the financial

marketplace (FAO and UNCCD 2015). For such incentive schemes to be successful, however, certain key principles have to be adhered to.

Enabling legal and policy framework
To stimulate forest development, governments must create the right environment for investment through supportive policies that address the barriers that constrain private-sector investment in forestry. As an example, the government policy of leasing degraded public forest land to private developers made forestry investment in Uganda more attractive to private investors, who were able to acquire land for planting trees. For every hectare of land leased to a private developer, 15% is reserved for the local community under collaborative forest management to enable it to participate in forest management.

Strong administrative approach and adherence to quality standards
Performance-based grant payments ensure value for money in addition to promoting good silvicultural practices. This approach means that rather than advancing money to farmers and expecting them to plant, farmers use their own money and are repaid for the trees they plant. And since the farmer/beneficiary must contribute some of the initial investment capital, and does not receive repayment until after the trees are planted, the risk of funds being diverted to activities other than forestry is significantly reduced. Performance-based payments also ensure adherence to quality standards.

Sustainability of financing for forestry investment
The successful implementation of afforestation programmes requires access to stable, reliable and long-term funding. Although grants and subsidies may be appropriate for covering startup costs to make forestry investment more attractive, subsidies alone tend not to be a sustainable financing mechanism. Funding gaps are likely to persist unless other innovative financing models are explored, such as credit financing from development banks to provide low-interest loans with long repayment periods. A sustainable forestry investment financing strategy should include a combination of funding from national environment funds, climate finance, development cooperation, other national budget areas, private-sector investment, NGOs, and non-traditional sources such as crowdsourcing (FAO 2015).

Interventions and capacity development
To deliver value to local communities, afforestation programmes must also address challenges at various parts of the value chain, from tree nurseries to tree planting, harvesting, processing and marketing. In addition, capacity development through training is needed, with research and development to provide data and information on the costs and returns of forest investments. Evidence-based research that takes into account local needs and realities is an important requirement to reduce the effects of any unintended negative impacts of plantations, such as biodiversity and water security concerns.

Conclusions

Financial incentives are essential in the initial stages of plantation establishment to trigger interest in forest investment, and these incentives have put Uganda ahead of its neighbours in East Africa in terms of plantation development. However, subsidies alone are not enough. Funding gaps are likely to persist unless other innovative financing models, mechanisms and instruments are explored, such as credit financing from development banks to provide low-interest loans with long repayment periods.

A good measure of an incentive's success is if it can be phased out as the plantations grow, being progressively replaced by indirect incentives such as interest rate policies, general taxes and trade policies.

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Seedballs: an innovative way to restore drylands

Teddy Kinyanjui

Germination of a seed from a seedball. Photo: Seedballs Kenya

Seedballs Kenya has pioneered a method for low-cost and efficient reintroduction of tree and grass species into degraded areas in East Africa. Seedballs are simply that: seeds inside a ball, which is made of recovered waste charcoal dust mixed with nutritious binders. The seedballs are inexpensive to produce and can be easily dispersed over large areas of land and land that is hard to reach. Using this method, some of our partners have been able to re-establish native trees in old illegal charcoal-making sites for as little as US$0.05 per established seedling. The range of species used includes 11 native trees (mostly acacias) and three grass species. Tree seeds are supplied and certified by the Kenya Forestry Research Institute, and grass seeds are supplied by the Rea Trust in Baringo. The seeds are not treated in any way, and a batch tracing system is in place to record their provenance.

The biochar coating helps protect the seeds from predators such as birds, rodents and insects and from extremes of temperature until rain arrives. Once they are soaked, the seedballs prolong a moist environment around the seeds to encourage germination. They are spread by hand or slingshot on the ground, or sown by air using crop-spraying planes, helicopters or drones, with the pelleting helping immensely in calibrating correct aerial application rates. Compared to planting seedlings, this greatly reduces costs and offers land owners and managers the opportunity to sow year-round, while

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also avoiding transplanting shock and helping seedlings to produce stronger roots and grow into stronger plants. By April 2020, a total of 10,230,750 seedballs had been distributed in more than 30 countries; operations began in September 2016. Depending on species, technique and site conditions, success rates of 10–70% have been observed.

Seedballs Kenya is a partnership between Chardust Ltd., who manufacture the seedballs, and Cookswell Jikos, who are responsible for sales, distribution and marketing. The initiative is aimed at people working on the rehabilitation of degraded land where the natural seedbank is so depleted that natural regeneration will be extremely slow or not possible. It also has great potential for enriching seedbanks, or being used together with other restoration techniques such as soil and water conservation to encourage faster growth.

Examples of ways to restore with seedballs. Photo: Seedballs Kenya

Forest and farm producer organizations in Ghana's drylands: key partners in restoration

Elvis Kuudaar, Sophie Grouwels, Pauline Buffle & Saadia Bobtoya

The ABOFA agroecology demonstration site in Forikrom, Techiman Municipality. Photo: Nana Kwaw Adams/ABOFA.

"Restoring degraded land sustainably and inclusively requires producer organizations to be at the heart from the start."

Introduction

Forest and farm producer organizations (FFPOs) provide logical entry points for effective, on-the ground actions to restore forest landscapes. These groups provide a platform to demonstrate and lobby for improved tenure systems and access rights. They motivate implementation, facilitate access to markets and capital, and offer a structure for providing capacity-building services for members (Buffle and Buss 2015).

Building on existing experiences, interviews and local surveys in Ghana's savannah zone, this article details how FFPOs can help build climate-resilient landscapes and ensure that multiple benefits are generated for local communities. It highlights how FFPOs that implement restoration can build strong and sustainable

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value chains, and promote integrated production and climate-resilient landscapes. With FFPOs driving the process, restoration can become a vehicle for creating a new natural resource asset base in rural areas.

FFPOs are crucial for restoration planning. Since their members are affected by dryland degradation, they are well placed as the primary actors to restore their landscapes, based on their local knowledge and ability to sustain good practices over time. FFPOs can be better integrated by governments and provided with the technologies they need for improved implementation. At the local level, this requires multi-stakeholder processes, innovative peer learning, direct funding to FFPOs, promotion of blended finance, and a focus on forest landscape restoration interventions that generate viable revenues. Targets should include not only the number of hectares restored or trees planted, but also the number of businesses developed to support restoration such as nurseries and new enterprises based on products flowing from restoration. These should include the number of new jobs created, for men, women and youth, and also, how community forest and land tenure and territorial integrity have been improved.

Producer organizations: logical entry points for restoration

Forest and farm producer organizations in Ghana's savannah region have long been involved in landscape restoration. Their range of action is wide, including reforestation, afforestation, agroforestry, managed natural regeneration, improved fallows, integrated agriculture, watershed protection, erosion control, wildlife protection, community forests and land management. They are often the main implementers and agents of change for landscape restoration, thanks to their roots in local communities, the multiple services they provide, and the scale of their constituencies.

Forest and farm producer organizations

Forest and farm producers are women and men, smallholder families, indigenous peoples and local communities who have strong relationships with forests and farms. They grow, manage, harvest and process a wide range of natural-resource-based goods and services for subsistence use and for sale. Forest and farm producer organizations are member-based, with internal governance that ensures that decisions are transparent and represent members' interests. They are often organized in tiers, each tier expanding the organization's influence from the local to the national and regional level. They support their members to share knowledge and experience, engage in policy advocacy, secure tenure and access rights to natural resources, improve land management, expand markets through economies of scale, build enterprises, and increase income and well-being. Village development organizations also fulfil similar roles.

Meeting community needs

In 1992, a conflict arose around a river that had dried up in Forikrom, in Techiman Municipality of the Bono East Region. It illustrates how FFPOs can create a bottom-up, demand-led dynamic, and shows that an understanding of traditional, cultural, social, environmental and economic aspects and rules is a crucial safeguard for locally supported landscape restoration.

An integrated farm at Forikrom, in Techiman Municiplaity. Photo: Nana Kwaw Adams/ABOFA.

After years of tensions and disagreements, it became evident that the Abrono River had become dry not because people had ignored traditional restrictions on drawing water on certain days, but because the forest protecting the river had been cleared for farming. Religious leaders, traditional authorities, local government and forest and farm producers then agreed that the solution was to plant trees. A few years later the river began flowing again and communities again had water for drinking and irrigation.

This process led to the creation of the Abrono Organic Farmers Association. The association gradually evolved into a 6,000-strong FFPO that has restored more than 12,000 hectares, improving vegetation cover, soil fertility and biodiversity. Restoration included plantations of cashew, mango and teak and 30 ha of fuelwood species as well as protection of sacred groves, introduction of agroecological farming practices and promotion of indigenous crops. Members also benefit from improved and diversified livelihoods through ecotourism in the river valley and a demonstration site that trains members in agroecological farming all year-round. The group also produces fertilizer for their own use and for sale.

Multiple services for restoration

Landscape restoration planning and implementation is a complex process. Legislation and policies influence tenure rights, which must be secure for sustainable restoration. Cultural aspects are reflected in local beliefs on land use and land inheritance. Appropriate technical services and inputs can complement local knowledge, and awareness campaigns can show reasons and ways to restore. And who will pay for restoration? Given this mix, agreeing to an integrated planning and implementation approach can be challenging. Restoration is sometimes planned in approaches that focus only on

one aspect, such as land tenure or site-level tree planting, without considering landscape dynamics, making it difficult to find common platforms that touch on multiple aspects at once. This is an additional reason why it makes sense to engage FFPOs at the outset.

The Tele-Bere Village Savings and Loans Association began landscape restoration in 2016 across the Bolgatanga East District in the country's Upper East Region. In addition to financial services, the association provided members with 20,000 tree seedlings for planting around their homesteads, in fields and on community lands, and raised awareness of the benefits of agroforestry and farmer managed natural regeneration. This helped to restore 1,000 hectares. Additional services provided to members included support to process shea (*Vitellaria paradoxa*) nuts, and collective action towards consolidating financial inclusion through investment schemes in non-timber forest product (NTFP) value chains that promote landscape restoration. The association included training of 500 women members of Tele-Bere in shea soap production; they each now produce an average of 40 boxes of soap per year, resulting in a 25% increase in their income. Tele-Bere members are also investing in vetiver grass cultivation for weaving straw baskets, leading to further income generation and landscape restoration.

The Kassena-Nankana Baobab Women Cooperative Union is composed mostly of women members in seven districts of the country's Upper East Region. It began work with harvesting and processing baobab and shea products — value chains that are mainly women-centred — before expanding and diversifying into other crop, livestock and tree value chains. It also reintroduced and promoted indigenous, drought-tolerant crop varieties, along with training in water harvesting techniques for dry-season vegetable production. The organization was also consulted on landscape policy processes at the local level, where members' views were solicited for developing bylaws on charcoal and tree cutting, and in local dialogues on protection of shea and baobab trees and allocation of collection rights for women. Another issue of concern is the weak regulation and protection of NTFPs outside government reserves. Ongoing work is facilitating the development of a framework that provides legal protection for productive dryland resources.

Increasing impacts at scale

In response to the Bonn Challenge, the Government of Ghana pledged to restore 2 million hectares of degraded land by 2030. To meet this target, planning and implementation is needed at the landscape level, and a range of public- and private-sector initiatives need to be set up or strengthened. However, individual forest and farm producer organizations are often overlooked, thus it became important to establish a national federation, the Ghana Federation of Forest and Farm Producers (GhaFFaP).

Beginning in 2018, the federation was established by several FFPOs who wanted to maximize their strength in numbers to build stronger and more profitable forest and farm-based businesses, and to contribute to shaping national policies for sustainable development and the promotion of climate-resilient landscapes. Membership in the federation is open to FFPOs in Ghana that share its objectives. The federation is supported by the Forest and Farm Facility under a five-year programme (2018–22) involving FAO, IUCN, AgriCord, and IIED. The federation was launched in March 2020 and has a total of 167,837 members across the forest, transition and savannah zones, 44% women and 56% men, with 20% of the total being youth forest and farm producers.

The federation has four strategic initiatives. These are (i) national dialogues focusing on access to finance and markets; (ii) sustainable financial transformation of FFPOs using village savings and

A tree nursery in Kassena Nankana District, Upper East Region, that supplies seedlings for the Kassena Nankana Baobab Cooperative Union. Photo: Julius Awaregya/KANBAOCU

loans schemes; (iii) the Green Ghana scheme for promoting environmental campaigns and integrated landscapes; and (iv) including charcoal producers in forest landscape restoration to promote sustainable practices.

The latter two promote integrated land-use practices and build resilient landscapes by bringing together six FFPOs in dryland savannah areas and twelve more groups nationally. This maximizes their collective strength to affect large-scale landscape restoration by influencing policy that supports restoration and building strong and sustainable business value chains that improve dryland restoration. Ghana has no effective legal framework on charcoal and fuelwood production, but there is currently a national consultative process towards this aim. The Ghana Federation of Forest and Farm Producers is also developing a green charcoal "brand" through the Charcoal Producers in Forest Landscape Restoration initiative. This has support from key stakeholders, including GIZ-FLR and the Energy Commission, to ensure that local views are incorporated in the emerging fuelwood and charcoal framework.

Restoration challenges

In addition to limited knowledge of the technical aspects of restoration interventions, the three main issues faced by FFPOs in Ghana are (1) unfavourable land tenure arrangements; (2) weak involvement in landscape planning and decision making; and (3) lack of financial support.

Dryland restoration through tree planting by KANBAOCU members in Kassena Nankana District, Upper East Region. Photo: Julius Awaregya/KANBAOCU

Unfavourable tenure arrangements

Tree tenure regimes in Ghana, especially for timber species, have been a longstanding challenge and barrier to landscape restoration. Naturally occurring timber trees are vested in the state and do not benefit land-owners, who therefore have little incentive to protect and nurture them on their farms (although non-timber trees outside government reserves are not affected by this). Furthermore, planted timber trees need to be registered through a complicated and time-consuming process that discourages most farmers from planting, and bureaucratic requirements for obtaining timber harvest and conveyance permits discourages their sale. The traditional land tenure system in most areas in Ghana does not allow non-family members to grow timber or other trees on farmland that was originally agreed on for farming purposes. Any intended changes to land-use require renegotiation with land-owners; this is a barrier to migrant farmers who may be willing to engage in tree planting and agroforestry.

There are currently no adequate legal frameworks protecting productive landscapes outside government protected areas regarding the exploitation of NTFPs such as those from baobab, moringa, parkia and shea trees. This leads to competing demands and land uses and can result in further degradation. For example, the value chain for shea fruit products is dominated by women, whereas men prefer to use shea trees for charcoal production; this threatens women's business opportunities. Improving women's access to productive landscape resources remains a major challenge; their risk of being marginalized needs to be addressed in the context of sociocultural transformation. There are also other competing lands uses, such as large-scale commercial farming, mining, road construction and human settlement, that affect investments in long-term landscape restoration interventions.

Weak involvement in landscape planning and decision making
To date, the involvement of FFPOs in landscape restoration planning and policy processes has been very limited and ineffective, and the few FFPOs that have been involved were only through local-level consultations. For example, the Tele-Bere association has been engaged with the District Assembly and the Department of Agriculture, and has participated in a consultative survey by the Energy Commission of Ghana as part of the national consultative process towards the development of a charcoal and wood fuel policy and district medium-term development strategy for Bolgatanga East District Assembly.

Lack of financial support
Funding options for FFPOs are inadequate for improving their role in landscape restoration, and the few donor agencies that are ready to support them do not in most cases provide investments for efforts beyond capacity building. To promote sustainable dryland restoration, support for increasing economic returns needs to be strengthened, such as improving and diversifying income sources from a combination of products that promote the development of integrated and climate-smart landscapes. As one example, farmers could be discouraged from environmentally damaging dry-season farming along riverbanks with financial incentives for appropriate small-scale irrigation.

Conclusions

In Ghana and elsewhere, FFPOs and forest and farm producers are on the front line of the risks and impacts of land degradation. But as has been illustrated during the Covid-19 crisis, FFPOs also have a key role in supporting or directly providing services that governments sometimes find it challenging to deliver. Supporting FFPOs is thus key to building long-term resilience to risks and shocks.

FFPOs build the capacity of otherwise isolated and marginalized women, men and youth producers to achieve financial, food and fuel security, increase their resilience and adaptability to land degradation and climate change, enhance their capacity to sustainably manage their lands and farms, and boost their participation in policy processes. FFPOs are rooted in and connected among themselves, and are built on the ownership of their inter-generational assets and based on local knowledge, which is a strong basis for building additional knowledge. Forest and farm producers are the members and owners of these FFPOs, and therefore no one knows better what their needs are. If they are engaged in finding solutions, they will be more motivated to implement them because of their obvious interest in improving their own situation. Also, through their organizational structure, peer-to-peer learning can lead rapidly to a wide uptake of good practices and achieve sustained results at scale. FFPOs therefore offer services to, and leverage the role of, local and national governments since they can assess producer needs and evaluate policy efficacy in ways that governments may not be able to. They can also greatly increase the participation and influence of members in policy processes that affect them (FAO 2014).

Recommendations

A recent web consultation and conference on the multi-dimensional resilience of smallholder farmers (AgriCord et al. 2020) acknowledged the importance of recognizing FFPOs as key partners that should be able to: (1) implement landscape restoration that is rooted in local needs and knowledge; (2) benefit from an enabling policy environment for restoration, including tenure rights; and (3) obtain funding to provide multiple services at scale. The consultation resulted in recommendations for policy makers

and partners to engage with FFPOs in creating a more enabling environment so that together they can better address risks and challenges. These are relevant for issues such as land-tenure reforms, FFPO integration in landscape planning and decision making, and the need for direct funding, as illustrated by the cases of FFPOs in Ghana's drylands.

The consultation also resulted in three main recommendations for local and national governments, regional organizations, investors and the private sector:

1. Ensure a greater recognition by policy makers of forest and farm producers' significant local knowledge and expertise in restoration practices, and their contributions to local, national and global restoration efforts. For example, the GhaFFaP Agenda 2030 includes a "national dialogue series" that will further promote the agenda of forest and farm producers.
2. Ensure the inclusion of FFPOs through grassroots and national-level dialogues to formulate, implement and evaluate national restoration agendas and land management in general, and in other mitigation and adaptation efforts that respond to social and environmental crises.
3. Mobilize investment and finance to support FFPOs to deliver services to their members that are readily accessible to investments in landscape restoration. This underpins their resilience. FFPO investments in restoration interventions and innovations should also reduce their risks with government support, and scale up by developing relevant financial instruments, blended finance, private-sector collaboration, lowered transaction costs, insurance schemes, and more flexible mechanisms. Furthermore, smallholders and FFPOs need to have access to climate finance to further support their technical capacity building in restoration efforts.

Restoration targets set through AFR100 and the Bonn Challenge are to be lauded, but the challenge remains actual implementation on the ground and at scale. FFPOs offer a way to ensure that this happens, to bring to restoration processes a connection with livelihoods and rural economies and to achieve the SDGs and climate targets. They are a natural ally and can help to lead the way forward.

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Sustainable charcoal value chains support dryland restoration in Ghana

Mercy Owusu, Daniel Abu & Joseph Asante

Charcoal production at Babatokuma, Kintampo, northern Ghana. Photo: Daniel Abu

In Ghana, charcoal provides 64% of domestic energy requirements, and is a major source of income in northern and transitional zones. Taxes and levies on charcoal trading are also important sources of revenue for traditional authorities (including local chiefs), local government and the Forestry Commission. But the industry remains informal and unregulated, and with a lack of coherent policies, charcoal production remains a key driver of dryland degradation and deforestation. The Nationally Agreed Mitigation Actions (NAMAS) and the Renewable Energy Act 2011 (Act 832) stipulate a district-based permit system for wholesalers, and a revenue-sharing regime. However, these initiatives do not insist on the need to restore land cleared for charcoal production, nor do they require the establishment of wood lots and native trees for future harvesting.

To assess how restoration and wood lots might operate in practice, 200 ha of degraded dry forest in Bono East Region, northern Ghana, is being restored through enrichment planting, natural regeneration and agroforestry in five communities. Communities were consulted at the outset, and they decided which native trees to plant when restoring natural forest areas, and which fast-growing trees to plant in wood lots. In parallel, the project works with communities, land-owners and charcoal producer associations to prepare management plans and monitoring systems, and to implement

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sustainable restoration. Charcoal producers are also being trained in using improved kilns to increase the wood-to-charcoal conversion efficiency. Together, these efforts are beginning to have an impact on community attitudes, as people now see how they can benefit from dry forest landscapes, and how they can help to restore them, rather than degrade them.

New policies related to charcoal production and trade are needed to help to protect dry forests from further overexploitation, and to encourage the development of sustainable value chains. This must be accompanied by support to, and promotion of, dialogue among communities, land-owners, smallholders, CSOs, producer associations, and others further down the charcoal value chain. Furthermore, this must be aided by appropriate financing mechanisms, introducing incentives, engaging the private sector, and building partnerships that attract investors, while promoting gender equality, youth involvement and ensuring broad inclusiveness.

Developing effective policies at the national and regional levels requires the participation of all stakeholders, to not only reduce the environmental impact of charcoal production, but also promote dryland restoration at the same time.

Weighing charcoal to be sold in the local market. Photo: Tropenbos Ghana

Land restoration requires a shift from quantity to quality: lessons from Tigray, Ethiopia

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Farmers prefer good-quality seedlings. Photo: Gebrehiwot Hailemariam

"Poverty is the result of an inability to work hard, rather than God's will" [local Tigray saying]

Introduction

Land degradation is not new in Ethiopia, and many dryland restoration efforts aim to improve local livelihoods and landscapes while building resilience in the face of climate change. Tree planting is one of the most common restoration techniques to improve livelihoods and keep the environment healthy. However, evaluations of previous efforts (Tigray Bureau of Planning and Finance 2018; Tafere et al. 2019) showed that relative to these gigantic initiatives, restoration through plantations was not very successful. Exclosures also did not yield the expected benefits and services. This article shares lessons and experiences from Tigray Region and elaborates the emerging shift from quantity to quality in restoring degraded lands.

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Tigray: a learning place for dryland restoration

Tigray is widely known for its attempts to address land degradation. This region in northern Ethiopia is a predominantly rugged and undulating dryland zone, creating niches for diverse vegetation forms ranging from Afro-alpine to desert types. Forest cover has been constantly depleted, mainly due to human factors (Birhane et al. 2017). This reduces the resilience of smallholders who depend on natural resources, leaving them more vulnerable to droughts and famines such as those of 1974, 1984 and 2003 and to the recent El Niño (Tafere et al. 2019). This has encouraged the government to invest in and contribute to massive soil and water conservation interventions, including stone bunds, gully reclamation, and exclosures on steep slopes, accompanied by reforestation and afforestation over the past 30+ years.

Importantly, community members have also been contributing up to 40 days of free labour per year to restore degraded landscapes, in addition to their contribution through government initiatives such as the Public Safety Net Program and Sustainable Land Management Program. These approaches have made the region unique in implementing effective mass mobilisation campaigns. Moreover, support from international development partners through various programmes has been instrumental in complementing efforts made by the people and government, and these collective actions have brought success stories for others to learn from.

- Tigray won the World Future Council's 2017 Future Policy Award for its restoration policy and achievements, and the farming community of Abreha We Atsbeha received the Equator Prize Award in 2012 from UNDP "in recognition of their outstanding success in promoting local sustainable development solutions for people, nature, and resilient communities." More than 2 million *Faidherbia albida* trees have regenerated naturally in a few years in response to the "1 billion *Faidherbia albida* seedlings" planting programme initiated by the late Prime Minister Meles Zenawi.
- Tigray is now much greener, with an increase in forest cover from about 3% in the 1990s to 17% in 2019 (Tigray BoARD 2020).
- The people of Tigray were mobilized to invest their labour in restoration, and over a 15-year period they have moved at least 90 million tonnes of soil and rock by hand.
- About 1.87 million ha have been restored using physical soil and water conservation (646,321 ha), exclosures (232,368 ha), plantations (171,482 ha), state forests (454,012 ha), natural forest (260,721 ha), and agroforestry (104,837 ha) (Tigray BoARD 2020).
- Groups from other parts of Ethiopia and other African countries have visited Tigray to see and learn. The efforts have also contributed to the Ethiopian commitment to restore 22 million ha as part of the Bonn Challenge and the African Forest Landscape Restoration Initiative (AFR100).

Achievements to date are very encouraging, but still not enough to meet growing community demands. The scale of restoration investments seems to be smaller than the scope and complexity of the problem (Gebreselassie et al. 2016). Concerns were raised by the Tigray government, Tigray think tank groups, NGOs and the community regarding why forest cover in Tigray has increased to only 17% (Tigray BoARD 2020). How to improve the effectiveness of reforestation and afforestation was debated, as all sides agreed that achievements are underwhelming when compared to the efforts made. The review did result in a change in mindset from quantity to quality, institutional arrangements, and the strengthening of extension services.

Farmer managed natural regeneration (FMNR) as a tool for restoration of degraded landscapes and improved management of exclosures: the case of Abreha We Atsbeha and many other parts of Tigray: Photo: Niguse Hagazi

Transforming the forest sector

The Forest Development, Protection and Utilization (FDPU) unit within the Tigray Bureau of Agriculture and Rural Development (BoARD) took an important step in deciding to transform the forestry sector in 2018. The focus was on what could be done differently during and after plantation establishment, exclosure management, enrichment planting, natural forest protection, and soil and water conservation to support reforestation and afforestation. The emerging shift in approach during this transformation came about from asking key questions.

- Why are increases in forest cover and its economic contributions not larger, despite efforts spanning more than two decades? And why is the contribution of (mostly eucalyptus) plantation forestry to regional forest cover only 17%, which seems too small an impact for the investment and low value for money? (However, this number does not include the many eucalyptus trees grown in compounds in Tigray, which represent a high value source of income to smallholder farmers.)
- Despite Tigray being well known for using exclosures as a tool for forest and landscape restoration, why are communities not benefiting more from them? Why are the results from some successful exclosures even backsliding? What is missing?

The main changes that occurred in response to this shift were related to institutional arrangements, tree establishment practices, and management of exclosures.

The local community, together with development partners and government staff, celebrate the successful completion of free labour contributions in 2019 to soil and water conservation to create zero runoff.
Photo: Gebrehiwot Hailemariam

Institutional arrangements

In 2018, the region decided to reorganise the FDPU unit, which used to be an experienced case team but with very limited decision-making powers or planning and implementation capacity. The reorganization resulted in the following changes.

- The FDPU team was upgraded to a directorate, which helped improve planning and implementation and allocation of budgets, with three sub-teams (forest development, forest protection and utilization, and agroforestry) established to execute them.
- A forest/tree seed centre was established to coordinate tree seed systems and build capacity, including the private sector. The centre identifies and maps tree seed sources and buys and supplies quality tree seeds that have undergone testing and certification. It also monitors the quality of all seeds, including imports, before distributing them to public and private nurseries.
- Private-sector involvement in raising seedlings has increased from 15% to 27% in the past three years. Government tree nurseries are also being privatized. This brings forestry services closer to farmers, with new arrangements moving from top-down and quota-based to a demand-driven tree seedling production system.
- Evidence-based planning and decision-making is now in place. Once the directorate was established this raised accountability questions, such as those related to the Tigray government investing millions in restoration, what happened and how much land has been treated and restored. A study team was established to answer these questions and to document evidence (Tigray BoARD 2020).

- The Mountain Development and Research Institute, the first of its kind in Ethiopia, was established in 2017 at Mekelle University in Tigray to build capacity in the region and country to support the sustainable development of mountain areas.

Tree establishment practices

Farming communities in Tigray are predominantly engaged in crop and livestock production, and extension services were aligned to that (Hagazi et al. 2019). However, based on learning from the shortcomings in achieving the expected economic, social and ecological benefits and services, the forestry sector extension approach was revised.

- Top-down decision-making for seed and seedling distribution was changed to bottom-up and context-specific distribution to help people plant the right tree in the right place for the right purpose. A strategic shift was made towards plantations, with each district divided into five plantation clusters and planting systems based on these clusters or on commodities, e.g., commercial/industrial, energy, construction, etc.
- The previous approach of mass mobilization for tree-planting without prior training was transformed to include training of key community members beforehand, with technical backstopping and assistance on hand for community groups and individuals during tree planting.
- Tree ownership was transferred to the groups and individuals who planted the trees, even trees in communal areas. An immediate result was a significant improvement in seedling survival rate: to 65–75% by 2019, with a five-year (2015–19) average of 56% (Tigray BoARD 2020). Before 2018, the average survival rate three to four months after planting was less than 50%, declining to less than 30% after 12 to 15 months. The FDPU directorate now aims for greater than 80% survival in the next five years.
- The approach moved from partial packages (i.e., with attention only to planting) to full packages, including post-planting care. A full extension package should also match species with intended objectives and purposes and include a management plan to be followed from pre-planting to aftercare. When establishing plantations, water availability must be considered in order to improve survival rates and growth performance.
- The approach changed from poor seedling production (measured in billions) to high-quality, demand-driven and objective-oriented production (in millions). Tree planting plans for 2015–17 included an estimated 3 billion seedlings, which was significantly reduced to 180 million in 2018, 120 million in 2019, and 100 million in 2020 – an annual rate that will be continued until 2025 for restoring more than 200,000 hectares (Tigray BoARD 2020).

Acacia decurrens seedlings exceeded 6 metres in height 18 months after planting when supported by improved management practices that included fencing, watering, mulching and composting. Photo: Niguse Hagazi.

On a restored hillside using exclosures, Tigray has become a place for beekeeping enterprises and youth employment. Photo: Niguse Hagazi.

- Improved support must be made available to private and community plantations and agroforestry, acknowledging that costs will increase if extension agents visit more individuals.

Management of exclosures

The way exclosures were implemented as a tool for forest and landscape restoration had its limitations. Silvicultural practices and assisted natural regeneration strategies that could have improved management and increased benefits were not permitted. Biomass production, biodiversity enhancement, carbon sequestration, reduction of runoff, beekeeping, etc., were other key benefits that were not pursued or measured. To enhance benefits and services, management and extension services for exclosures were changed.

- Application of silvicultural practices in exclosures: Practices such as pruning and thinning allow communities to earn direct benefits while improving exclosure performance. In 2019–2020, some 25,000 ha of exclosures received silvicultural treatments; in 2021–2025, it is planned to expand this to a further 125,000 ha (Tigray BoARD 2020). This was a strategic policy shift from "fully closed" to "allowing for limited inclusion of communities" and creating a sense of ownership by allowing limited harvesting of wood and forest products for livelihood support.
- Strengthening bylaws for exclosures: Enforcement of bylaws was not consistent, leading locals to say, "if you cannot protect the invasion and looting of your father's land or property, then be one of the looters" (Tafere et al. 2019). Formulation of bylaws should involve the consent of all segments of society, with clear equity in participation and benefit-sharing mechanisms.

Local communities constructing conservation-based bench terraces in an exclosure: the case of Gergera watershed in Atsbi district. Photo: Niguse Hagazi

- **Hillside exclosures with bench terraces**: This also serves as an employment opportunity; for example, for 1,116 landless youth and 647 women who were engaged in restoring 1,270 ha (Tigray BoARD 2020).
- **Exclosures as corridors to connect remnant natural forests and church forests**: This is valuable for conserving biodiversity and counteracting adverse "island" effects; for example, by linking *Desea* and *Hugumbrda* dry Afromontane forest remnants.
- **Establishment of firebreaks**: Due emphasis is now given to establishing firebreaks and related infrastructure in state and natural forests that are highly susceptible to fire.

Conclusions

Dryland restoration should be facilitated and enhanced through dynamic and participatory decision making processes. Progressive and reflective learning drive change in decision makers (in communities and in government) towards a better understanding of why institutional arrangements, seedling quality and management matter to successful dryland restoration. Restoration attempts should be evidence based, and rigorous research is needed in: (i) tree planting techniques, including private sector participatory models and community engagement; (ii) sustainable and affordable tree establishment techniques to improve tree survival rates; (iii) drastically increasing post-planting care to improve plant development and their longer-term functions to people and the landscape; and (iv) how best to manage the trade-offs between locking up land and forest in exclosures and providing sustainable livelihoods for nearby communities.

Exclosures should be managed in ways that increase economic benefits to local communities and generate more information that can influence decision-making processes. The lessons from Tigray need to be well documented and shared with other parts of Ethiopia and other African countries for scaling up. For effective dryland restoration, support from development partners — including donors and governmental and non-governmental organisations — is crucial and must be continued in order to realize social, economic and environmental impacts as quickly as possible.

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Multipurpose benefits of *Acacia saligna* in the drylands of northern Ethiopia

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Acacia saligna for reclamation of gullies as woodlots. Photo: Niguse Hagazi

Land degradation in dryland areas is closely associated with high rates of rural poverty, which threatens rural livelihoods. Trees are well-known agents for ameliorating degradation; could they also integrate readily into existing farming systems and support smallholder livelihoods?

Six years of research supports the view that when managed as a multipurpose agroforestry tree, *Acacia saligna* can meet these requirements in northern Ethiopia. This work examined tree benefits and determined suitable management approaches. Initial on-farm and research station trials were established by World Vision and the Tigray Agriculture Research Institute, with further studies through a partnership with Mekelle and Wageningen Universities.

Genetic testing of naturalized populations found a high degree of genetic diversity, suggesting that selection might unlock potentially valuable ecotypes. Multi-year provenance resource stands were

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established using local selections and some Western Australia provenances, to conduct farmer-led selection of two promising forms: a pole ecotype with a straight form, and a multipurpose ecotype with a tendency to produce extensive foliage.

Trees were integrated readily into farming systems in various forms. Pruning to 1.8 to 2.3 metre height prevents goat damage, and provide valuable dry season feed in January–May. An *A. saligna* – wheat alley cropping trial showed that overall production including fodder and fuelwood from hedgerows, was greater than from wheat alone. Seeds also provide a high-protein supplement and improved egg production of laying hens. Beekeepers noted that *Acacia saligna* flowers in the hot months of March and April, provided bee fodder when few other species are flowering. Wood quality meets the standard required for the manufacture of medium-density particle board, generating more income for smallholders.

The use of *Acacia saligna* is scalable, with seedlings raised in nurseries. In conservation areas, trees had beneficial effects on native herbs, grasses, shrubs and macro- and microorganisms. Potential invasiveness was not confirmed, but trees favour the recovery of undergrowth and act as nurse trees for indigenous species. In addition to multipurpose benefits, the tree's drought tolerance, fast growth and high biomass production could encourage wider adoption, once invasiveness risks are mitigated, but will require the support of policy makers and the availability of the two ecotypes to improve smallholder income and livelihoods.

Farmers pollarding *Acacia saligna*. Photo: Peter Cunningham

Restoring the gum arabic belt in Sudan with local communities

Elsayda Mohamed Elhassan Elfadul, Tarig Elsheikh Mahmoud, Hassan Mofadel, Erkan Ozcelik, Simon Rietbergen, Faiza Siddig & Brent Simpson

Shared landscapes - camels browsing on gum arabic trees. Photo: Simon Rietbergen

"It's not just about establishing and tending trees. Restoration requires support for smallholder producers in dryland value chains."

Introduction

Gum arabic, harvested from the nitrogen-fixing legume trees *Acacia senegal* (locally called *hashab*) and *Acacia seyal* (locally called *talha*), provides smallholders in Sudan with up to 38% of their annual income. Gum revenue also comes at a crucial time, the end of the dry season, when it provides investment capital for rainy-season activities such as fattening livestock and growing crops. Gum trees are often grown in association with annual food crops, increasing crop yields through enhancing soil fertility, improving water infiltration and lowering evaporation by reducing wind speed, thereby improving the efficiency of water and fertilizer use. Thus, gum trees can significantly boost crop yields and reduce household vulnerability to climate change stresses.

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A successful pilot project was carried out on gum arabic production in Kordofan, Sudan. Several factors are essential for scaling up the results to achieve larger landscape restoration goals, including climate change adaptation and mitigation. This article recommends how to make a better case for investment in dryland restoration with international financial institutions, including those interested in climate change, and how to encourage private-sector investment from large commodity buyers to partner with smallholder farmers to improve the chances of long-term sustainability.

The context

Agriculture, land use and gum production

Agriculture is a mainstay of the Sudanese economy, accounting for over 30% of GDP since the secession of South Sudan in 2011. More than 80% of the labour force is employed in agriculture and livestock herding; the vast majority of these people are poor and food insecure smallholders. Around 70% of agricultural GDP is generated by such smallholder producers, each of whom cultivates less than 4.2 hectares, with 90% of livestock production from pastoralists and smallholders. After livestock and sesame, gum arabic is the third leading contributor to agricultural export earnings. Between 2014 and 2016, Sudan accounted for 70–77% of total global exports, which are valued at US$150 million per year.

Gum arabic prices have remained remarkably strong, despite a steady increase in worldwide gum supply: from around 30,000 tonnes in 1992 to 110,000 tonnes in 2016. The gum arabic belt of Sudan covers an area of 520,000 km^2 across the middle of the country. The gum belt landscape is shared by farming and pastoralist communities. Most of the latter are mobile; nomadic pastoralists predominantly herd camels in the northern part of the gum belt, and transhumant pastoralists, with their cattle and sheep herds, spend the rainy season in the north and middle of the gum belt and move south in search of pasture and water during the dry season and in times of drought.

Climate change impacts

Sudan is one of the most vulnerable countries in the world to climate change, facing rising temperatures that are leading to severe and increasing moisture stress. In North, South and West Kordofan states, 98% of agriculture is rainfed and greatly exposed to weather and climate threats. An analysis of expected climate change impacts on key crops — under the representative concentration pathway (RCP) 8.5 scenario, using IFAD's climate adaptation in rural development (CARD) tool (IFAD 2019) — shows a decline of 7% for millet and 12% for groundnut by 2039. An analysis carried out for the first national communication to the UNFCCC (Republic of Sudan 2003) projected a 24–62% decline for millet and a 49–71% decline for sorghum by 2060.

Policy and institutional failures

Gum arabic production in Sudan has suffered from a number of policy and institutional failures. Consecutive government policy interventions — including a government monopoly on gum exports — reduced the price paid to producers in the early 2000s to around 10% of the world market price (Mahmoud 2017). This led many farmers to stop harvesting gum, which had a clear negative effect on the natural resource base, as many gum trees were also felled for charcoal production. However, since the government monopoly on gum exports was abolished in 2010, the price paid to producers has increased to about 20–25% of world market prices. This is still quite low in comparison to other major cash crops in Sudan such as groundnuts and sesame, for which the price paid to producers is 30–50% of the world market price. In response, the national government, donors and NGOs have

Gum arabic being cleaned prior to export. Photo: Simon Rietbergen

been working together with private-sector investors to increase prices for smallholder gum producers in Sudan, with the objective to reach at least 50% of the world market price.

Sudan's land-use laws are sector-based, leading to policies that are not well adapted to dryland environments that are shared by farmers and livestock keepers for at least part of the year. This lack of cross-sectoral coordination has been aggravated in past decades through the occupation of key livestock routes by conflicting land uses, such as large-scale mechanized farming, often without any consultation with local communities.

A pilot project with promising results

Low prices paid to smallholder gum producers

The 20–25% of the world market price that smallholder producers in Sudan receive for their gum is quite low in comparison to other globally traded commodities. The poor market position of gum producers in Sudan is partly explained by their limited access to formal financial services, which means that they have to rely on the sheil system, under which they are required to sell their gum for low prices (around 50% of local auction market prices) to village traders, in return for receiving pre-financing. For gum, however, as for many commodities, it is relatively easy to support smallholders in the market by organizing producer groups. This enables them to sell larger quantities and, by helping them to improve the quality of their produce, to attract buyers who are willing to pay higher prices for premium-quality gum. This was the basic idea behind the Structuring the Gum Arabic Sector (SGAS) project.

The support for Structuring the Gum Arabic Sector (SGAS) project

The SGAS project (AFD 2013) was implemented by Sudan's Forest National Corporation (FNC) from 2014 to 2018 in Sheikan Locality in North Kordofan State, and was funded by the *Agence Française de Développement* (AFD). The Institute for Gum Arabic Research and Desertification of the University of North Kordofan provided technical assistance. Among its activities, SGAS worked with 30 smallholder gum arabic producer associations to strengthen their organizations and support their compliance with the international AIPG standard for producing clean and dry gum (AIPG 2014), and to facilitate contract-farming agreements with two gum exporters, Elemats/COMATS and Habeebi. Of the 15 gum arabic producer associations supported by the SGAS project that worked with Elemats/COMATS, 14 still supply high-quality gum under contract to the company today, and receive the El Obeid auction market price plus a 10% premium, which amounts to more than double the sheil price.

Contract farming is not without its problems, however. The power imbalance between commodity buyers and smallholder producers — even when the latter are organized in larger groups — can give rise to inequitable arrangements. There are also risks to the buyers, especially if they provide cash advances and/or inputs to smallholder groups who then sell their crops to other buyers instead (called "side-selling"). On the positive side, contract farming can be the first step for smallholders wanting to build autonomous cooperatives, helping buyers gain an advantage in their (export) markets, which increasingly require information on who producers are and whether they were adequately remunerated for their product. Under the SGAS project, the producer prices are pegged to the gum auction market price, which reduces the risks for the smallholders, and the 10% price premium paid by Elemats/COMATS reduces the incentive for side-selling. In addition, the SGAS project established a simple system for producers to receive daily phone text messages detailing gum volumes traded and prices obtained in nearby auction markets.

Farmer showing daily text message with gum market information.
Photo: Simon Rietbergen

An unexpected benefit of the SGAS project was that some participating farmers spontaneously started to sow Acacia seeds with their other crops. This was not an objective of the project, but it provided an additional positive impact, with a reversal of the cutting of gum trees nearly two decades ago.

This led FNC and The Food and Agriculture Organization (FAO) to collaborate on the development of a new project proposal, Gums for Adaptation and Mitigation in Sudan (GAMS), currently under consideration by the Green Climate Fund. GAMS would explicitly link improvements in smallholder gum value chains to incentives for land restoration (FAO and FNC 2020).

Acacia senegal tree gum being harvested with the improved "sonki" tool. Photo: Tarig Elsheikh Mahmoud

Challenges addressed

As with any pilot project, some challenges in the SGAS project became clear only after implementation started. One challenge was the high level of mistrust between smallholder producers and gum buyers. The project proponents had scheduled meetings to start discussing contract farming arrangements, but found they had to spend months at the outset to address this mutual suspicion and reset the relationship. Another more complex problem was the inequity within smallholder producer groups. Gum tapping and collection require pre-financing for inputs such as jute bags and for hiring additional labour, but the leaders of some smallholder gum arabic producer associations who received pre-financing did not share this equitably with all their members. To improve transparency and accountability within the associations, FNC and Elemats/COMATS required them to adopt a number of management and accounting tools, including the use of individually signed receipts from members for all pre-financing received.

Scaling up

Many land restoration projects succeed at a small scale, but attempts to replicate them at a larger scale are fraught with difficulties. (A well-known positive exception to this is farmer managed natural restoration (FMNR) in Niger and elsewhere in West Africa.) One key reason for the inability to scale up is that quantitative differences (larger areas, more people) have qualitative implications as well, including (i) the land-use context, (ii) transaction costs for private-sector companies collaborating with smallholder producer groups, and (iii) the elasticity of prices for non-timber forest products. To address this, GAMS activities will focus on using the gum arabic value chains as an incentive for restoration; the aim is that the gum bush fallow system will become FMNR again once gum has been

Gum stored in jute bags to prevent coagulation and discolouration. Photo: Tarig Elsheikh Mahmoud

re-established in degraded areas, and that coppicing of gum trees can take place once production slows down after 25 to 30 years.

Land-use context

When small-scale projects restore a few hundred or even a few thousand hectares, the impacts are mainly local, and any stakeholder issues related to land-use changes can usually be solved at the local level. When restoration takes place over tens of thousands or hundreds of thousands of hectares, however, stakeholder issues become harder to manage, and can give rise to major land-use conflicts, especially in Sudan. Therefore, in addition to restoring 125,000 ha of gum agroforestry systems, the GAMS proposal to scale up the SGAS project also includes rehabilitating transhumance routes and water points, and encouraging farming and pastoralist communities, supported by national rangeland authorities, to actively engage in the co-management of these areas.

Managing private-sector transaction costs

Gum buyers face significant costs in managing contract farming arrangements with producer associations, and in providing pre-financing and inputs for gum tapping and collection. Elemats/COMATS has not scaled up, for example, despite being successful in maintaining purchase contracts over the six years since the start of the SGAS project. One way to address this issue is to involve microfinance institutions, but they consider agriculture as a high-risk sector and consequently, their financial products and conditions are generally unattractive to smallholders.

Price elasticity and terms of trade

Gum arabic is exceptional among non-timber forest products (NTFPs) in terms of the total size of the world market (more than US$150 million/year) and because both export trade volumes and market

prices have increased substantially over the past two decades. This is atypical; most NTFPs have limited markets, and increases in supplies tend to bring product prices down – a key factor to consider when designing projects that aim to incentivize restoration by improving smallholder NTFP value chains. The GAMS project will work with auction markets to create a separate product standard to empower producer groups to sell their premium-quality gum for a fair price, even if these groups have not concluded gum farming contracts. Gum arabic is an important commodity in many other Sahelian countries, such as Chad, Mali and Nigeria, providing a path for scaling up restoration even further. NTFPs that are used in the cosmetics industry, which is investing in research and development on natural products, could provide similar restoration incentives for smallholder farmers, e.g., with *Boswellia* and *Commiphora* gums.

Conclusions

Making the case for restoration projects with donors who focus on climate change is surprisingly challenging. Climate change scenarios for African drylands tend to vary considerably, which complicates adaptation rationales, and as landscapes are often shared between farmers and pastoralists, optimizing the land-use practices of one group in terms of climate change could reduce the resilience of the other. One argument that can make adaptation projects more attractive to donor funding is that many of them can also generate climate change mitigation benefits, by avoiding land-use emissions or through carbon sequestration, although data has to be gathered and a robust methodology (e.g., FAO's Ex-Ante Carbon Tool, Ex-ACT; FAO 2020) is needed that uses conservative estimates to quantify benefits.

Many public-sector donors say they appreciate efforts to involve the private sector, whether these are smallholder producer groups or larger companies. However, when public-sector donors receive a project proposal that collaborates with the private sector, they worry that public funds might potentially subsidize activities that could be funded through private investment, or that they could help powerful companies to take advantage of small-scale producers. One way to avoid these issues — which was used in the GAMS project proposal — is to use public funds strictly to build the capacity of smallholder producer groups who are in most cases not (yet) "bankable," and to facilitate their interactions with commodity buyers and microfinance institutions. The facts that contract farming arrangements piloted under the SGAS project are fully transparent and pay producers a premium price on top of a competitive auction market price are also helpful in this respect.

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Restoring grasslands in Kenya's Rift Valley

Elizabeth Meyerhoff, Peter de Groot & Billy Jones

Harvesting grass seed as income generation. Photo: RAE

"Much emphasis has been place on afforestation, but grassland restoration is equally important."

Introduction

Grasslands are a prerequisite for rearing livestock, and livestock is the mainstay of people's existence in drylands. As one Kenyan woman put it, "without grass there is no livestock, without livestock there is no life." Based in the lowlands of Baringo County in Kenya's Rift Valley, RAE (Rehabilitating Arid Environments) Ltd. has worked for 38 years to develop a successful socio-ecological model that benefits people and dryland environments. RAE adapts its rain-fed land restoration techniques to each site, while continually revising its activities and strategies to the changing environmental and social dynamics of different areas and communities.

Today, RAE's tried and tested methods are being widely replicated by government and non-government organizations, and most importantly, by agropastoralists and pastoralists, who profit

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Pokot RAE field prepared for planting, June 2019 (above) and rehabilitated, October 2019 (below). Photo: RAE

directly from their restored and well-managed pastures. RAE's long term efforts demonstrate that sustainable pasture restoration is not only possible, but that it improves the environment, livelihoods and food security and reduces conflicts.

Approach and methods

The Baringo lowlands illustrate both the problems and the potential of dryland areas. Approximately 70% of Baringo County is unproductive arid or semi-arid land, denuded of vegetative cover and biodiversity. Erratic rainfall and intense storms, worsened by the deforestation of watersheds and intense grazing, have increased erosion, runoff and flash floods. Poverty and food insecurity are now common amongst Baringo's growing population of around 667,000, most of whom are agropastoralists who directly depend on their land and livestock for survival.

Since 1982, RAE has been committed to a participatory grassroots approach of listening and learning. Stakeholders are consulted and involved in every stage of the land rehabilitation process, and have played an integral part in the organization's development and changes. Although traditional nomadic pastoralism is no longer tenable in Baringo or in many other areas of Kenya, people and societies are resilient, continually adapting to changes to meet altered (and more modern) needs. RAE has persevered, despite minimal funding and a small staff, by adjusting and expanding its programme to meet the ever-changing challenges and needs of people and dryland environments.

RAE is a constant local presence. It facilitates participatory restoration in response to community requests on a cost-sharing basis, providing training and advice so farmers can maximize diverse benefits from their land. And with adequate rainfall, restored areas can become productive and

A rehabilitated private Il Chamus field. Photo: RAE

profitable in three months. Successful restoration is not seen as an end in itself; sustainable management is essential. However, restored areas will be sustainably managed only when local people benefit directly from them.

After years of field trials, RAE has identified five fundamental components of sustainable land restoration:

1. Assessments – environmental and social.
2. Training – interactive and practical.
3. Land rehabilitation – site-specific land preparation and water harvesting techniques that maximize rainwater harvesting (developed by RAE Founder and Director Murray Roberts).
4. Sustainable management and follow-up – collaborative monitoring and evaluation.
5. High-quality grass seed – site-specific indigenous dryland species, tested for yield and germination.

Although RAE offers all five services to its growing clientele, most organizations only want grass seed. But without appropriate land rehabilitation methods grass will not germinate. And without follow-up training and monitoring, grass fields will not be sustained and benefits will not be realized.

The preferred grass for Baringo farmers is the highly drought resistant native *Cenchrus ciliaris*, with its strong, fibrous deeply penetrating roots. RAE also supplies seed from other indigenous grasses, including *Cymbopogon pospischilli, Enteropogon macrostachyus, Eragrostis superba* and *Sehima nervosum*, recommending a mix of species for best results.

Direct benefits

RAE's on-the-ground results are clearly visible, with indigenous grass and tree species flourishing. Community uptake continues to increase, because people generate substantial income from their productive plots through the innovative strategies they've developed, such as leasing fields for grazing, breeding and selling improved livestock, and selling livestock fattened on fields, as well as milk, baled hay, thatching grass and grass seed. Additionally, people can now sustain their livestock throughout the year, including during droughts.

RAE has directly rehabilitated more than 2,400 hectares, comprising 924 private fields (each 0.5–16 ha) demarcated and fenced by long-term residents and managed by individual families, and 75 community fields (0.5–200 ha) managed by communities or groups, including shareholders' and women's groups. In addition, thousands more hectares have been rehabilitated with RAE grass seed. Many families in Baringo are changing their maize fields into pasture, based on their experience that grass is a more viable and profitable crop due to the effects of climate change. Maize is not successful every year and cultivation is costly, whereas once grass is established, well-managed pastures require minimal inputs.

Observations show that private pastures are better managed and at least ten times more productive and profitable than community fields. A single RAE private field can generate benefits for one family in cash and in kind of more than US$16,500 per year though multiple, well timed activities. The most profitable cash earnings are from livestock fattening (up to US$4,825 per year from 2 ha) and grass seed harvesting (US$2,200 per year from 16 ha). Today, RAE concentrates on fulfilling ever more requests to rehabilitate private pasture fields. In contrast, other organizations still insist on restoring community land even though many of these efforts fail due to poor management. Even when groups define their own management structures (electing leaders, writing bylaws, etc.), complex group dynamics and socio-political obligations can undermine implementation. However, RAE is fully aware that both community and private land rehabilitation is needed in Baringo and beyond, especially amongst more traditional pastoralist societies where land is less scarce and cohesive community structures encourage sustainable land and livestock management practices.

Youth and women

RAE pays special attention to youth and women, while respecting the cultural norms of pastoralist communities based on patriarchal and polygamous traditions. Youth from drylands are disadvantaged by poor education and few employment opportunities and often migrate to urban areas. Unemployed youth are also primarily responsible for violent unrest between pastoralist groups. Today, however, more youth are restoring pastures, realizing that they can earn good income and gain the status and independence they aspire to.

Women now do vital work as dryland environmental managers and entrepreneurs and own or manage 82% of new private pastures in Baringo, earning new incomes from cutting thatching grass and harvesting grass seed. Most of this income goes directly towards meeting household needs, especially food and school fees, which improves their household's wealth and status. Pastures have also decreased women's overburdened workload. In Baringo and other pastoralist areas, men and youth often leave to seek employment, leaving women to care for livestock in addition to everyday domestic tasks. Also, new pastures near their homesteads help increase household nutrition through milk

Exchange tour to RAE during training of Samburu women. Photo: RAE

production. For example, an Ilchamus mother of four and sole family breadwinner began in 2015 by sowing a half-hectare pasture and another in 2017, earning US$1,002 from grass seed, US$580 from hiring out fields for grazing, and US$2,234 from selling milk from their two cows and dry-season grazing for 15 goats. She became a trainer of trainers for local women and visiting pastoralists on exchange tours, and she proudly explained how she bought one of her cows with proceeds from her grass fields, unusual for a pastoralist woman.

Broader benefits and impacts

Economic. The fact that men, women and youth can generate significant incomes from restored pasture has far-reaching social impacts for drylands. People now fatten smaller herds of quality livestock for sale rather than keeping large herds that further degrade the land, and have a secure source of fodder and hay to keep livestock alive during prolonged dry periods. People now value their semi-arid lands, which they previously considered useless wastelands, but now see as having value for sustaining their diverse natural resources and for providing income.

Reduced conflicts. The importance of pasture development as a means of conflict resolution is particularly pertinent in Kenya. Armed conflicts, on the rise due to the lack of grazing, are becoming more lethal with the availability of AK47s and with disadvantaged youths willing to take up arms. Baringo is well known for armed raids, especially amongst the more traditional pastoralist Pokot people. RAE has worked in Tiaty Sub-County, East Pokot since 1998, planting 72 pasture fields; requests from Pokot have recently surged, with over 59 still to be fulfilled. One of RAE's most successful dryland farmers is an influential Pokot elder who recently requested assistance in planting another 60 hectares. He

has laid down his arms and encourages other Pokot pastoralists to sow grass. In 2018, the Baringo Governor visited his successful pastures.

Policy. Influencing policy, legislative and social change is also a core activity. Examples include RAE's contribution to the development of the National Policy for the Sustainable Development of Northern Kenya and Other Semi-Arid Lands of Kenya (2005), the Wajir County Rangeland Management Bill (2017), and developing much-needed regulations for high-quality dryland grass seed with the Kenya Plant Health Inspectorate Service in alignment with those available for highland areas. RAE is also advocating that grass be recognized as a crop, with fines for illegally grazing pastures being considered and passed upwards through local governments.

Carbon sequestration. The organic carbon in the top metre of soils worldwide is more than all that held in the atmosphere and vegetation combined (FAO 2017). Globally, in the top metre, dryland soils sequester 27% of all soil organic carbon, but this is lost when soils are degraded. After 20 to 30 years in Baringo, restored grasslands contained 45 tonnes of soil organic carbon per hectare, some 50% higher than in degraded grassland (32 t C/ha^{-1}), compared to 50 t of C/ha^{-1} in pristine grasslands (Mbaabu et al. 2020). One restored field increased soil organic carbon by an average of 1.4% annually over 30 years to a depth of one metre. However, the roots of the main indigenous grass planted by RAE can extend to a depth of over 2 metres, much deeper than is usually evaluated in soil carbon sequestration studies. Therefore, scaling up grassland restoration would make a substantially greater contribution to sequestering carbon at the global level than generally realized to date.

Soil erosion. It was estimated that soil erosion due to vegetation loss resulted in 5 million m^3 of sediment being deposited in Lake Baringo each year (Pencol Engineering Consultants 1981). This led to the raising of the lakebed and likely exacerbated the severe flooding in 2013 and 2020. In July 2020 RAE documented the submergence of 496 homesteads, 47 shops, 4 schools and 3 health centres, and the displacement of 5,700 people. With severe flooding continuing through mid-October these figures are expected to triple. RAE's rehabilitation efforts have proven to reduce soil erosion and lake sedimentation, while dramatically increasing biodiversity completely lost to areas outside RAE fields. An investigation (Mganga et al. 2010) into three indigenous dryland grasses shows that mature strands of the most popular grass planted by RAE can increase infiltration by nearly 80%, reduce runoff by almost 70%, and reduce sedimentation by some 98%.

Nyasi ni pesa (grass is money)

RAE began in 1982 as a donor-funded restoration initiative that concentrated on tree planting. When bilateral funding ended in 1994, the RAE Charitable Trust was formed on request from local Tugen, Ilchamus and Pokot agropastoralists, and it evolved in response to emerging challenges. The trust focused on grassland rehabilitation. Aware of the limitations of projects that offered only short-term funding, RAE Ltd. was formed in 2015 to scale up a profitable business model that would benefit both communities and the company, working under the approach of *nyasi ni pesa* (grass is money). Committing to a truly participatory approach must accommodate the financial needs of local pastoralists, especially as increasing financial pressures mean they must spend more resources to find ways of securing an income (Lesorogol 2003).

RAE developed a social enterprise model to provide a secure income so people could continue to restore and maintain grasslands, and also made a pioneering effort in building a thriving local

industry around high-quality dryland grass seed. Previously, grass was not cultivated as a crop in drylands, nor was dryland grass seed considered a profitable commodity by pastoralists. RAE provides subsidized inputs (primarily land rehabilitation, grass seed and training) to individuals and groups, buys the seed and sells in bulk to conservancies, ranches and government institutions, both in Kenya and internationally. Sales of quality seed handpicked by local women reached 12.4 tonnes by 2019, and the proceeds were reinvested in more restoration so the operation can continue to grow.

Financing social enterprises

There is huge potential for this model to be scaled up and expanded across the drylands of Kenya and other countries. But there is one major obstacle: financing. The traditional donor-based model is unsuited to financing effective, sustainable restoration initiatives. These efforts are usually not sustained once funding ends, and they provide no incentives for communities to be custodians of their own environment. Slow uptake of these traditional models is also due to a lack of market incentives, insecure land tenure and resource-use rights, high up-front costs and labour intensity (Obersteiner 2017). Uptake is further hampered by financial, legal and structural barriers that prevent organizations and local communities from restoring and maintaining degraded grasslands. It is crucial that financing institutions fund solutions that acknowledge and innovatively tackle these barriers.

RAE's success is due in part to its ability to understand the form and scale of the ecological, social and economic challenges facing the drylands where it works. Its success is the result of continual research and monitoring of the environment and community for nearly 40 years, which continue to inform activities and strategies. Long-term recording and analysis is generally not funded, however, and RAE struggles to compile, digitize and analyze its records due to limited resources. It is essential that funding for research be prioritized alongside funding for operational expansion.

Taking success to another level

If global leaders are to take their commitment to reducing land degradation seriously, best practices need to be rapidly scaled up into viable projects in other dryland regions. Every dryland environment has its own individual set of circumstances, challenges and cultural complexities. RAE's model works because it responds to the society, culture and environment of specific areas. The first principle of bottom-up, participatory restoration — working within pre-existing local networks — is what make RAE's model effective. To achieve this, seamless collaboration between all actors is essential, and sustained commitment in terms of expertise and funding is needed.

RAE has demonstrated that scaling up land restoration is entirely feasible, given political will and resources. Local people can make good profits from restored grassland, which provides incentives for sustainable management and environmental benefits from reduced erosion and increasing soil organic carbon. Perhaps the much-needed long-term support will be forthcoming when there is international recognition that restored grasslands are profitable to the local and global economy, and that tropical grasslands are as important for carbon sequestration as the world's forests are, and therefore of fundamental concern to everyone.

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Linking restoration and sustainable wood fuel initiatives in Sahelian Cameroon

Denis Jean Sonwa, Abdon Awono, Lydie Flora Essamba à Rim & Pamela Tabi

Sacks of charcoal for sale in Kagleri village, Mora sub-division, Far North region. Photo: Jean Hugues Nlom

Cameroon's commitment to the AFR100 initiative to restore 12 million hectares of degraded land puts emphasis on the country's three dry northern regions. One quarter of this commitment is supposed to take place in the Far North Region. The highest degradation of this region has clear impacts on livelihoods; in addition, the dependence of local communities, internally displaced people and refugees on unsustainable wood fuel collection contributes to further degradation.

Supporting Cameroon's restoration program is a component of the CIFOR project "Governing multifunctional landscapes in sub-Saharan Africa: managing trade-offs between social and ecological impacts", funded by the European Union (www2.cifor.org/gml). The initiative is contributing to knowledge, defining and testing options, and identifying networks for more sustainable wood fuel value chains in the region, in order to manage trade-offs between social and ecological impacts. The annual urban consumption of firewood in the region was estimated in 2016 to be 460,551 tonnes, plus 9,677 tonnes of charcoal (International Forestry Review 18:S1).

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There were difficulties in satisfying the demand for firewood and charcoal by bringing them from the southern humid forest zone of the country, as initially planned by government and its partners. Promotion of sustainable wood fuel initiatives in this Sahelian zone is urgent and high priority. After a scoping study in 2018, CIFOR established a platform — including public forestry and environment bodies, universities, local government, civil society organizations local communities, refugee and UNHCR — to find sustainable options.

Together the stakeholders identified three key goals during a problem analysis workshop: (i) better understand the drivers of the demand for wood fuel, the formal and informal institutions involved, and the transboundary trade with Chad and Nigeria; (ii) support research and new technologies for making charcoal from household and agricultural waste to reduce pressures on natural ecosystems; and (iii) attract long-term investments for charcoal production, including plantations. Workshop participants also agreed that food security should be addressed, and that fruit trees should be included in silviculture plans to encourage local communities to participate.

A study on transboundary trade is being carried out, and the results will be valuable in establishing wood fuel regulations at the regional level through the Lake Chad Basin Commission. Since restoration happens in a specific socioeconomical context, knowledge of the direct and indirect drivers of degradation that inform initiatives to reduce environmental pressures is very useful in framing a sustainable response. In the Far North Region, the driest part of Cameroon, the promotion of sustainable wood fuel value chains is clearly seen as an important component of restoration.

Transporting firewood for sale in Kousseri, Cameroon. Photo: Jean Hugues Nlom

3

Cross-cutting issues

Photo, previous page: Woman carrying firewood in Droum, Zinder, Niger. Photo: NCBA CLUSA.

Local land-use plans, bylaws and conventions reduce resource-based conflicts

Brook Johnson & Douglas Steinberg

Agroforestry parklands in Droum commune, Niger. Photo: NCBA CLUSA

"Simple, widely disseminated local conventions have decreased conflicts and promoted restoration in densely populated rural areas."

Introduction

Burkina Faso and Niger face rapid population growth, climate change, armed insecurity and conflicts over resources. In response, the National Cooperative Business Association CLUSA International (NCBA CLUSA) implemented the Resilience and Economic Growth in the Sahel – Enhanced Resilience (REGIS-ER) project. This saw the development of 17 local conventions across the two countries at the commune (rural district) level to assure the sustainable use of natural resources, strengthen responsive decentralized governance, and reinforce citizens' rights and responsibilities. These conventions have had considerable success in improving natural resource management, increasing farmer managed natural regeneration (FMNR) on 5% of farmland and reducing violent conflicts by 74% in targeted communes. They were less successful, however, in managing forests, pastures and ponds far from the villages.

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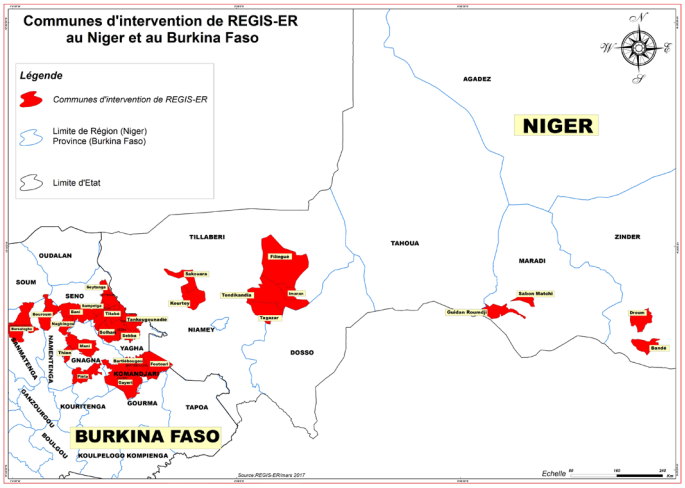
Project context

REGIS-ER was a seven-year project (2013–2020) funded by USAID. It promoted the resilience of chronically food insecure communities in 570 villages in 25 communes in 6 regions, covering 35,732 km² of agropastoral zones in Burkina Faso and Niger. In the target areas (Figure 1), drought and flooding lead to malnutrition and migration and to conflicts over limited resources.

Figure 1: REGIS-ER intervention areas



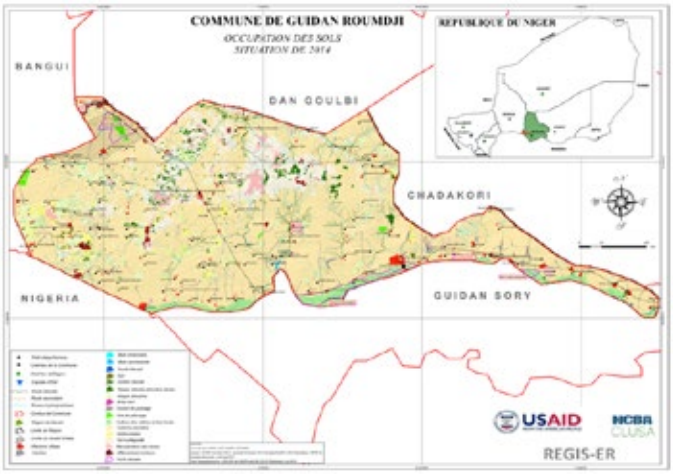
By reinforcing communal institutions, refining procedures, and increasing financing, the project took a systemic approach to addressing communities' resilience needs; improving soil fertility, agricultural production and sanitation; and building assets, especially among women, to ensure household food security. And as drought is an ever-present risk, the project built capacity for famine early warning and timely local response to crop failure and conflict.

Local conventions

The goal of local conventions is to assure the conservation and sustainable use of natural resources on commune lands, to satisfy growing demands while maintaining productivity and ecological and social well-being. Local conventions were first developed in the 1990s in Senegal and Mali as experiments in decentralization and alternatives to costly production forestry. In 2005, GIZ identified 150 local conventions in West Africa (Alinon and Kalinganire 2008) and there are considerably more now.

Local conventions consist of two parts: a land-use plan and a set of bylaws. The land-use plan (*Plan Communal d'Occupation et d'Affectation des Sols*, PCOAS) is a decision-making tool to guide planning and management of natural resources at the commune level, and is supported by commune bylaws that regulate natural resource use. Land-use plans include an inventory and map of natural resources, with land-use zones defined and demarcated according to potential use (see Figure 2), and a land-use tool to support decision-making. Natural resource bylaws define guidelines for access, use and management of natural resources and provide a platform for dialogue among stakeholders with conflicting interests. Bylaws must be aligned with national laws.

Figure 2. Land-use zones in Guidan Roumdji, Niger



NCBA CLUSA adopted an 11-step process for developing conventions.

1. Sensitize commune leaders to the benefits of local conventions;
2. Establish a technical steering committee and sub-zone committees;
3. Train sub-zone committees in environmental analysis;
4. Draft a land-use map;
5. Assist sub-zone committees to elaborate a land-use plan (*Plan Communal d'Occupation et d'Affectation des Sols*);
6. Propose commune bylaws (steering committee, zone groups, municipal council, chef de canton, village chiefs, and other stakeholders);
7. Have bylaws validated by population and technical services;
8. Obtain approval of the local convention by the mayor and *prefet/sous-prefet*;
9. Disseminate the local convention;
10. Train people in commune monitoring and evaluation; and
11. Integrate the local convention into commune development plans.

The project facilitates active participation, involving stakeholders from communities, local government councils and technical services, including women, youth, herders and other resource users who represent a wide variety of interests. Local conventions should be reviewed, renewed and aligned with other commune development priorities every five years.

The average cost of developing both land-use plans and bylaws was calculated to be about US$19,000 per commune. Local NGOs are also being trained to implement and renew local conventions after the project ends. It is estimated that without external facilitators, consultant fees and other overhead costs, the cost would fall to about US$10,000 per commune, and would be even less if maps and land-use plans were simplified. Mayors said they might be able to cover approximately US$3,500 from their budgets, but the rest would have to be subsidized. There would be a greater incentive to invest in local conventions if they could generate revenue for local government, but this could happen

A community meeting in Gamba, Zinder. Photo: NCBA CLUSA

only where resources have sufficient market value that could be levied or valued in some other way to generate revenue.

Implementing local conventions

This study examined 5 of the project's 17 local conventions, in the communes of Manni and Bouroum in eastern Burkina Faso, and Tondikandia, Droum and Guidan-Roumdji in Niger (Johnson et al. 2019). Data was collected in October 2019.

Conforming with decentralized governance policies, the project collaborated with village development committees: the *Comité Local de Développement* in Niger and *Conseil Villageois de Développement* in Burkina Faso. Within their respective communities, these village-level institutions establish subcommittees that are responsible for specific activities, such as implementing the local convention. Since the members of these local development committees are unpaid, they can only carry out simple natural resource management monitoring activities that are not time consuming.

The project also cooperated with partners to expand the network of land commissions that register land titles at the village level: the *Commission Foncière de Base* in Niger, and the *Commissions Foncières Villageoises* or *Commission de Conciliation Foncière Villageoise* in Burkina Faso. In addition to monitoring land tenure, these groups are authorized to manage natural resource conflicts. Unlike the case of the village development committees, land commissions can generate modest fees that can incentivize agents. Since the committees are newly established and have a scope that occasionally overlaps with traditional authorities, they are not yet completely functional.

Herd of sheep grazing near a seasonal pond in Maradi Region, Niger. Photo: NCBA CLUSA

Tondikandia, Droum and Manni proposed village development committees as their primary management structure. Guidan Roumdji and Boroum designated land commissions to manage their local conventions, with village development committees playing a supporting role.

Effective management of common resources (forests, pastures or ponds) that are distant from village areas requires specialized management groups with specific technical training. The project did not invest in the establishment of these groups, but instead relied on similar groups established by other development programmes. While this would build on existing institutions rather than multiply them, at least in theory, most were pasture management or soil conservation groups whose aims were to support the goals of the project that created them, rather than broadly manage natural resources in a commune.

All local convention bylaws include taxes, fees and fines associated with the use or abuse of the commune's natural resources. These mostly reaffirm existing customary or national levies that provide little or no returns to the commune council or management groups responsible for implementing local conventions. Customary fines are received by the aggrieved party, and only 10% of federal levies on natural resources are returned to the communes. Guidan Roumdji, Manni and Bouroum developed mechanisms to capture revenues at the communal level; Tondikandia and Droum did not, relying on meagre tax revenues from the central government to implement their local conventions.

Impacts

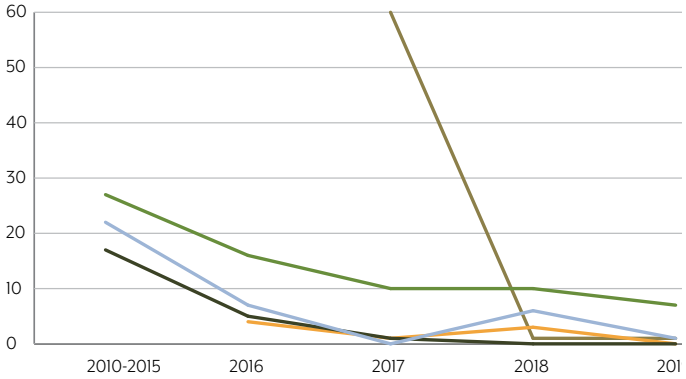
Farmer managed natural regeneration

Village sub-committees fostered farmer managed natural regeneration (FMNR) on 13,742 ha, a 4.6% increase that was attributed to project activities alone. The commune of Manni, which developed its

local convention three years previously, achieved an impressive 32% increase in FMNR coverage, from 30 to 65 trees/ha.

Conflicts over natural resources dropped dramatically, by 74% in four communes (see Figure 3). Results from Droum, the only commune where data was detailed by the nature of conflict, suggest there was little change in the type of conflicts experienced. However, data was collected in October 2019, so not all conflict data for that year is included. Furthermore, the local convention in Manni was validated in May 2017 and disseminated in July, with the large number of conflicts that year occurring several months later. Local authorities argue that the implementers did not yet have the capacity to resolve these conflicts in July.

Figure 3. Decreases in conflicts over time in the four surveyed communes.



Factors for success

Participatory elaboration and diffusion

The collective acceptance and subsequent enforcement of local conventions at the village level is vital. Acceptance and enforcement must be ensured through a highly participatory process, otherwise the convention will represent only the elite and will exclude disenfranchised groups (Granier 2010). Given the vast size of some of these communes, steps 3, 5, and 6 of the process were carried out in central towns at the sub-zone level to reduce cost. Although this constrained the project's ability to engage all citizens, the process required the involvement of at least two inhabitants from every village, representing all levels of society in a sub-zone. In the commune of Tondikandia, for example, 0.5% of the adult population was involved, which is comparatively inclusive for such a large-scale participatory governance process.

The project also fostered strong acceptance of the new conventions; communities translated them into local languages and disseminated them through a month-long series of local radio broadcasts presented by local leaders. In densely populated rural areas in the Sahel, this can lead to commune-wide acceptance and self-enforcement in village areas, mitigating the need for complicated institutional structures to monitor, adjudicate and enforce rules. With robust and legitimate traditional leadership in both countries, a vigorous dissemination of rules is equal to, or perhaps even more important than, massive participation in the elaboration of rules.

Recognized structures

The sustainability of local conventions is anchored in their legitimacy with and endorsement by technical services (Johnson et al. 2020). Even though village development committees are limited in scope both technically and geographically, they are nonetheless recognized by commune government and technical services, which strengthens their authority and effectiveness. Local conventions are also intended to be integrated into commune development plans to reinforce their legitimacy. However, as decentralized planning occurs only every five years, communes must wait for the next planning cycle to include local conventions in their plans; so far, only one (Tondikandia) has been integrated.

Systems-based approach

Most projects that facilitate local conventions establish local natural resource management groups, and strengthen the municipal council's natural resource management committee, encouraging exchange between the two. Building resilience, on the other hand, requires a systems-based approach, including public, civil society, and private-sector actors. Local conventions are more sustainable when their local governance context is vibrant and responsive.

As part of its wider governance work, the project developed civil society organizations called citizen working groups to facilitate communication between village stakeholders and municipal councils. Farmer producer groups generate revenues and increase community capacity to pay taxes or fees. Community-based service providers sell seedlings to farmers. Village savings and loan associations provide credit to producers and service providers. Land tenure commissions provide land titles to support the restoration of degraded lands. All of these efforts reinforce the viability of local conventions.

Challenges

Tailoring the intervention to capacity is a critical factor for sustainability. The main challenge to the sustainability of local conventions is their lack of capacity to generate revenue. Two factors determine their financial sustainability: the value of local resources, and the ability to capture fees and fines at the commune level. However, the amount of vegetative resources are relatively low in the Sahel, and often of comparatively poor value, so establishing communal levies can be politically controversial. The only revenues generated by a local convention in this study were fees associated with artisanal gold mining in Bouroum, and few Sahelian communes can tap resources of such value.

Limited financial resources clearly constrain management groups, who require tools, technical training and financial incentives to effectively perform their duties. Fortunately, the enforcement of herder/farmer and FMNR infractions in village areas can be carried out collectively with light oversight from village development committees, requiring neither incentives nor tools.

Approach

Areas that have valuable forest, mineral or animal resources and are difficult to monitor require land-use plans and specialized teams for sustainable management. However, the project demonstrated that widely accepted bylaws have promoted FMNR and prevented conflict in densely populated rural areas, even with limited enforcement. There is little reason to elaborate costly land-use plans that require oversight by incentivized committees if there are limited opportunities to generate revenue. Thus, a simple approach is recommended for local conventions in populated Sahelian agricultural zones, contingent on changing or emerging situations.

First, simple bylaws should be established, with a focus on farmland and pastures monitored by land commissions or village development subcommittees to reduce conflict and promote FMNR. Then, if communes can demonstrate that forest, mineral or animal resources can generate the revenues needed to ensure effective management of their commons, a land-use plan should be drafted. Bylaws should address appropriate communal tax schedules and revenue sharing, and an accompanying decree should establish technically competent management teams, define their roles and responsibilities, and clarify their lines of authority. If the project had adopted this conditional approach, then Tondikandia, Droum, Guidan-Roumdji and Manni would still have decreased the frequency of conflicts and increased FMNR, but at a considerably lower cost.

Conclusions

Much has been written about the dramatic regreening of southern Niger achieved by FMNR. While it is a simple concept, practising FMNR requires a shift in the collective mindset that can be challenging to achieve. Reij and Winterbottom (2015) describe six steps: (i) identify existing FMNR successes; (ii) build grassroots movements to promote FMNR; (iii) address relevant policy and legal issues; (iv) implement a communication strategy; (v) strengthen agroforestry value chains; and (vi) expand research activities. Local conventions effectively promote steps 2, 3 and 4, and with an active land-use plan, step 5, demonstrating their effectiveness in fostering FMNR.

The Institute for Economics and Peace (2019) reports that Burkina Faso and Niger rank 104th and 116th of 163 on the 2019 Global Peace Index, with the economic cost of violence accounting for 9% of Niger's GDP. However, Higazi and Abubakar Ali (2018) affirmed that "local conventions [in Burkina Faso], which stipulate the rights and responsibilities of farmers and pastoralists and establish mutually-agreed enforcement procedures, that are sanctioned by local state authorities…[are]…helping to promote conflict prevention, mediation, and resolution."

The project's local convention approach demonstrates that inclusively developed, widely disseminated land-use bylaws, enforced by a network of village groups, is the most sustainable model for reducing conflicts and increasing tree cover in densely-populated, agricultural regions of the Sahel.

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Scalable and equitable governance in farmer managed natural regeneration

Matt Kandel, Chanimbe Benamba, Rahinatu S. Alare, Genevieve Agaba & Kate Schreckenberg

A woodland bush farm during the dry season in Talensi, northern Ghana, with crop residues remaining in the fields. Near this farm are long-term fallows, an important land use within parklands. Photo: Matt Kandel

"Regreening landscapes is as much a social enterprise as it is a biophysical and technical one."

Introduction

One of the most successful and cost-effective approaches to landscape restoration in African drylands is farmer managed natural regeneration (FMNR). This involves pruning and thinning to manage the regrowth of tree stumps, roots and seeds (Reij and Winterbottom 2015), and leads to improvements in crop yields, carbon sequestration, biodiversity and household income (Binam et al. 2015). FMNR is especially suitable for drylands, where survival rates from tree planting are frequently low. But despite the successes of FMNR, there are challenges in upscaling.

Who determines who should benefit from certain tree products? And which local institutions play a role in managing the resource

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demands of livestock grazing, household energy supply and crop farming? Such questions are important for ensuring that dryland landscape restoration in Africa is scalable and socially equitable. They also underscore the importance of empowering stakeholders – local land users in particular – in the governance of landscape restoration initiatives. Resource governance and tenure are increasingly recognized as integral components of landscape restoration. This is especially so for Africa's drylands, where customary institutions mediate access and control over trees and land in different ways. Research suggests that assessing tenure rights in practice, rather than rights in law, should be prioritized when planning forest and landscape restoration interventions (McLain et al. 2018).

This article uses experiences from FMNR interventions in northern Ghana to answer these questions.

1. Why do resource governance and tenure matter for FMNR interventions, and why have they so far not received the attention they deserve?
2. What are the constraints to achieving scalable and equitable resource governance in FMNR interventions?
3. How can FMNR projects better engage with resource governance and tenure, with the aim of improving scalable and equitable project outcomes?

This article integrates practitioner perspectives with insights from research in 2019–20 that used qualitative and participatory data collection tools to explore FMNR uptake in three communities in Talensi District, Upper East Region (Kandel et al. 2021). This leads to four recommendations for enhancing scalable and equitable resource governance in FMNR interventions in Africa's drylands.

Resource governance and tenure in FMNR: Why such little attention?

Resource governance and tenure matter for restoration. Governance approaches should address key equity concerns that include how benefits, costs and risks are distributed; who participates in decision making and how; and whether the voices, rights and values of all stakeholders are recognized and respected (Nunan et al. 2018).

Why do governance and tenure not receive enough attention when it comes to FMNR? Two main reasons were seen for this in Ghana. First, the biophysical and technical aspects of restoration still attract more attention than the social and political dimensions (Elias et al. 2021). Second, FMNR is not about planting trees. Instead, by supporting the regrowth of native trees, FMNR recognizes the value of local knowledge and traditional agroforestry practices. This may have led to an assumption that resource governance and equity issues are less likely to arise in FMNR since seemingly nothing 'new' is being brought to these landscapes.

This calls for shifting attention to how existing social differences in access to and control over natural resources influence who wins and who loses from the regeneration of native trees (Kandel et al. 2021). Rights to benefits from trees in African drylands depend on factors such as kinship, gender, residence status, seniority and social class, with implications for which trees are retained and how they are managed.

Stone bunds in one of the study communities. Photo: Matt Kandel

FMNR in northern Ghana

Northern Ghana lies within the Guinean and Sudanian savanna agroecological zones, which contain parkland agroforestry systems, with scattered trees on permanently cultivated village fields and long-term fallows (Boffa 1999). In 2009, World Vision Ghana piloted FMNR in nine communities in Talensi District. By 2012, 161 ha of forest and 336 ha of cropland had been restored (Weston et al. 2013). Of the farmers who adopted FMNR, 94% reported increases in soil fertility and 66% reported improvements in soil erosion (Weston et al. 2013).

World Vision Ghana has since implemented FMNR in 48 more communities in Talensi, and scaled it up to the districts of Bawku West, Garu-Tempane, Jirapa, Mion and Kassena-Nankana. Using an integrative approach, FMNR is implemented alongside livelihood diversification and sustainable land management activities such as crop residue management and stone bunding. Training in agronomic practices enhances on-farm resource availability and reduces the need for resource extraction from dry forests.

Strengthening governance in community FMNR

World Vision Ghana supports existing institutions in identifying degraded areas to be restored. These areas — which can reach up to 50 hectares in size — also serve as community FMNR 'learning centres.' Site selection is led by the chief, traditional leaders, district assembly person and household heads; the latter must agree to allocate customary land (over which they hold usufruct rights) to the community. Community FMNR groups have 20 members who are selected with gender equality and inclusion of vulnerable groups in mind. These groups also play key roles in farmer-to-farmer extension, with a focus on sharing knowledge of tree and shrub management. World Vision Ghana also supports

A community FMNR site, with shrubs in the foreground and mature shea trees (*Vitellaria paradoxa*) in the background. Photo: Matt Kandel

communities in formulating bylaws, which become codified according to customary norms and practices. Bylaws promote tree and shrub regeneration on community FMNR sites and prohibit cutting – only branches pruned during FMNR may be removed for firewood.

Along with the FMNR groups, World Vision Ghana also supports the establishment of 20-member fire volunteer groups in each community. With training from the Ghana National Fire Service, volunteers are responsible for preventing and controlling fires, especially in the dry season, and are mandated to report any transgressions to the chief. As with the community FMNR groups, gender equality and the involvement of vulnerable groups are key criteria for selecting members of the fire groups.

Key findings

- Community sites are important for regenerating trees on a scale larger than plot level and for improving biodiversity (Weston et al. 2013).
- Emphasizing gender equality and the involvement of vulnerable groups in selecting members of FMNR and fire volunteer groups demonstrates social inclusion.
- The governance model used in community FMNR sites is important for supporting equitable resource access and is consistent with how local communities customarily govern communal land.
- Farmer-to-farmer knowledge sharing on FMNR has led to enhanced capabilities in sustainable land management. During on-farm transect walks, for example, farmers explained their decisions to keep young trees in their fields, especially *Faidherbia albida*, and many indicated that they used to remove all thorny trees during land preparation, whereas now they retain them.

A farmer pointing towards a community FMNR site, with a small firebreak also visible. Photo: Matt Kandel

- Supporting governance structures that facilitate the prevention and control of bush fires is important for FMNR. During interviews on the benefits of FMNR, many ranked "reduced bush fire" highly, with one person stating that this is a fundamental benefit, providing the basis for people to realize other positive outcomes such as improved soil fertility, shade and windbreak.

Constraints to scalability and equity

Notwithstanding resource governance successes, other factors constrain the equitable upscaling of FMNR in northern Ghana.

Tree and land tenure. Who can benefit from which trees, where, when and how, is socially differentiated and affects how benefits are distributed. In some areas, for example, chiefs and sub-chiefs reserve harvesting rights to the valuable pods of the African locust bean (*Parkia biglobosa*), which disincentivises other farmers from retaining parkia seedlings on their farms and potentially hastens their decline in the landscape (Poudyal 2011). Also, the household that leases the land often prohibits the tenant farmer from harvesting fruit from any shea trees there.

Pastoralists and FMNR. Supporting the participation of pastoralists in FMNR has been a challenge in Talensi. Called "Fulani" by many people (though not all pastoralists are Fulani), they are socially and politically marginalized, which complicates efforts to include them.

Cross-scale governance. Communities that did not receive technical support in resource governance from the project did not always adopt the land management practices necessary for upscaling regreening. A key reason was the inability to prevent and control large bush fires due to a lack of inter-community resource governance.

Communally managed pasture in Talensi in January when the harmattan wind blows in from the Sahara Desert. Photo: Matt Kandel

Weak government enforcement. Lack of government enforcement against deforestation, particularly of shea for charcoal and African rosewood (*Dalbergia* spp.) for timber exports, works against efforts to upscale tree regeneration. Cutting shea trees also produces inequitable outcomes, since women are the main processors and beneficiaries of products from the fruit. Commercial and small-scale surface mining also pose regulatory challenges.

Chieftaincy conflict. Chiefs and sub-chiefs make important contributions to upscaling resource governance, but chieftaincy conflicts, which at times turn violent, have made it difficult to scale up inter-community resource governance structures.

Recommendations

Achieving scalable and socially equitable resource governance in FMNR requires overcoming constraints and coalescing around a shared vision for regenerating landscapes. Lessons learned from this experience led to four recommendations.

1: Assess local tree and land tenure systems when planning FMNR interventions. Mapping local-level resource power dynamics help to mitigate potentially inequitable outcomes, especially with communally managed forests and pastures. Statutory laws and policies often exert little influence on local-scale natural resource management in rural Africa. This is because in practice local land users' rights which often diverge from statutory law, influence how they invest in and manage natural resources. However, alternative tenure models such those proposed by McLain et al. (2018) can help answer the question of who is likely to win and lose from the regeneration of indigenous trees. If FMNR is paired

with enrichment planting, as demonstrated in Ethiopia (Hagazi et al. 2019), extra attention needs to be paid to the tenure-specific aspects of each tree species.

2: Ensure that all land user groups, including pastoralists, participate in decision-making processes to achieve the socially equitable upscaling of FMNR. As a restoration approach that is specially tailored to drylands, FMNR should avoid a model that focuses only on farmers. Ensuring that vulnerable and marginalized social groups such as women, migrants and pastoralists are included in resource governance is a key part of socially equitable restoration. The commons governance model supports social inclusion and equity when FMNR is used to restore degraded and deforested areas. Although supporting pastoralist participation in FMNR in Ghana has proven challenging, evidence from Niger shows it is possible, but only if governance structures are inclusive (Tougiani et al. 2009). Addressing the political marginalization of pastoralists in Ghana is outside the scope of an FMNR intervention, but excluding pastoralists from resource governance will have consequences, particularly when it comes to regreening important grazing areas such as pastures and woodland fallows.

3: Asking "by whom and for whom?" is an important framing device for strengthening social equity in FMNR (or any restoration intervention), but so is asking "where?," as this affects upscaling efforts as well as who can participate in FMNR. One response from farmers in Talensi was that they could not practise FMNR on village fields due to the absence of living rootstocks; this mirrors other research findings (Binam et al. 2015). To upscale socially inclusive FMNR the following four questions are important. (a) Are there other locations within the landscape such as fallows, pastures or riparian areas where FMNR technically might have more potential? (b) In what areas are land users and social groups most likely to benefit from FMNR? (c) How will tenure arrangements affect who benefits from FMNR in these areas? (d) Are there adequate incentives for land users to practise FMNR in these contexts? Ultimately, supporting local land users in deciding where in the landscape FMNR is most viable is key to scaling up this approach, and communities must also feel incentivized to invest their time and resources.

4: Strengthen resource governance for regreening by supporting community-led, inter-community collaboration, with cross-jurisdictional and cross-sectoral support from government, traditional institutions and non-governmental organizations. This is essential to achieving sustainable outcomes. Governance structures may also need to include conflict management and conflict reconciliation mechanisms. In Talensi, for example, farmer-herder dispute resolution initiatives offer a potential platform for socially inclusive land use planning and resource governance. It is important that governance structures recognize and respect all land users within the landscape.

Conclusions

Regreening landscapes is as much a social enterprise as it is a biophysical and technical one. The recommendations in this article draw on the experiences presented here and reflect the importance of resource governance and tenure within the context of FMNR. They aim to support ongoing efforts at achieving scalable and socially equitable resource governance in related interventions in Africa's drylands. Making the case for FMNR requires tailoring the message to local needs, expectations and aspirations, and acknowledging that different social groups and land users maintain different visions for dryland landscapes. This plays to the strengths of FMNR, as it is based on recognizing the value of local agroforestry knowledge and practices. This socially equitable premise sets FMNR apart from many other restoration approaches that are still too often top-down in design and implementation. It therefore should continue to guide FMNR interventions in African drylands.

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Understanding the dimensions and context of participation in restoration

Aster Gebrekirstos, Niguse Hagazi, Emiru Birhane & Meine van Noordwijk

Women constructing conservation based bench terraces in Gergera watershed, Ethiopia. Photo: Niguse Hagazi

Past failures in forest landscape restoration were due in part to less consultative, more top-down approaches and policies, with purely local initiatives often hampered by government rules and limited resources. Based on empirical evidence, local participation must be at the heart of sustainable restoration from programme inception. But what exactly does participation mean and practically entail? There is no shortage of terms to describe participation, but they often lack clear meaning or indicators to measure them. Also, they are often based on the assumption that initiatives are externally led and locals can participate, rather than the other way around. However, participation can be better evaluated and understood by examining the dimensions and the context of participation.

The "who?" dimension of participation constitutes the upstream and downstream stakeholders, local leaders, government staff and foreign personnel. The "what?" dimension constitutes the kind of participation that is present throughout the project cycle, in decision-making, implementation, access to benefits and evaluation. The "how?" dimension is the basis, form, extent and effectiveness of participation. It calls for behavioural analysis that gives insights into why participation takes place, continues, declines, or follows a particular pattern. The social, cultural, economic and political context

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of participation must also be considered. But predicting participatory behaviour has not proved easy, since people with more or less the same background and involved in more or less the same activity can act and interact very differently.

Evaluating restoration projects often relies entirely on qualitative or short-term assessments by scientists and managers from external partners and local government. They have a vested interest in reporting positive results, rather than relying on objective, quantitative, long-term, field-based monitoring. Five indicators are essential for measuring the effectiveness of participation: (i) decisions are based on shared visions; (ii) implementation is clear and action-oriented; (iii) communities are encouraged to experiment and to articulate their values, which are included in decision making; (iv) open communication and collaboration among stakeholders is fostered throughout; and (v) participation is socially and economically appropriate.

Restoration is a process, not a single act, and will be successful only if undertaken by local people themselves – massive investments alone cannot succeed. Success should therefore not be measured only by the number of trees planted or the number of hectares restored. Instead, it must be assessed by looking through local people's eyes, relating to their expectations, and understanding whether the process allows them to protect their land in the long term.

Women farmers watering seedlings and managing a tree nursery. Photo: Niguse Hagazi

Enhancing women's rights and lives through gender-equitable restoration

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Members of a women's group engaged in restoration activities. Photo: Barbara Vinceti / Alliance of Bioversity International and CIAT

"Access to and control over land are key to involving rural women in restoration."

Introduction

Gender differences and gender inequalities in rights, status and responsibilities significantly shape daily rural life and life cycles in rural West Africa (Levasseur 2003), where women face significant constraints in participating in activities aimed at restoring forests and farmland. Yet, they also find innovative ways to overcome such constraints, such as collective action and the creation of mutual support groups. In Burkina Faso, rural women are mobilizing such groups to improve their living conditions through sustainable resource management, and many NGOs, projects and

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associations are supporting them in these endeavours. By organizing themselves into collectives that can be targeted by development institutions, women improve their access to technical, financial and material support and training, build their capacities, and acquire new knowledge and resources to actively participate in land restoration.

In Burkina Faso and elsewhere in West Africa, women's limited access to and control over land severely hinders their ability to engage in restoration activities. Limited rights to land are a result not only of formal policies, but also of customary rules, which vary according to ethnicity, village, social status and the position of women in polygamous families (Konate 2006). Unequal ownership of assets such as equipment, fertilizers, tools and improved seeds — coupled with longstanding disparities between men and women in access to formal education, information, and agricultural extension — also has negative impacts on women farmers' ability to adopt innovative restorative practices (Njobe and Kaaria 2015).

This article specifically addresses three questions: What motivates women to invest time and effort in the restoration of land and forests? What obstacles do women face in implementing land and forest restoration activities? How do restoration activities affect the living conditions of women?

Methodology

This article reports the results from two studies conducted in 2018–19 in the Central Plateau of Burkina Faso. The first was conducted in three villages in the rural commune of Laye, Kourwéogo Province, 50 km northwest of the country's capital Ouagadougou. Most of the farm and forest land in the area has been degraded by overexploitation. The second study was conducted in three villages in the commune of Zitenga, Oubritenga Province, where the shallow and relatively infertile soils that prevail are vulnerable to erosion and runoff. The Mossé communities involved in the study are patrilineal and practice agropastoralism. Various methods were used to carry out the studies.

In Laye, semi-structured interviews collected the experiences and perceptions of women and men farmers and of resource persons from decentralized state services, officials of various organizations involved in promoting land restoration, municipal advisers, village development councillors, and customary authorities. Participants were chosen to represent this diversity of backgrounds and experiences. In-depth interviews and oral histories with 40 women farmers aimed to understand their involvement and experiences in restoration and in women's self-help groups engaged in restoration. An observation grid and field log were used to record observations and events and compare women's narratives and actions. Moreover, five focus group discussions, each with eight members of women's self-help groups, were conducted. Themes included motivations for land restoration, preferences for different types of restorative practices, and factors that support or hinder women's adoption of such practices.

In Zitenga, interviews and direct observation were used to gather data on innovative practices as well as constraints to their development or adoption, and on differences between internal and external innovations. Data were also gathered on social connections through which innovative practices are shared and adapted, taking into account the economic and social range of the various actors involved. To this end, 118 interviews were conducted with women and men farmers, who were selected to represent different social and demographic groups, and with resource persons, including heads of local associations, customary authorities, local state officials, and village development councillors.

Fenced plots under the care of a women's group. Photo: Barbara Vinceti / Alliance of Bioversity International and CIAT

Restoration techniques

Farmers in Laye and Zitenga are involved in a range of restoration activities on farmland and in forest areas.

- *Zaï* pits (staggered holes or basins of varying sizes, depending on soil type), to improve agricultural production and the recovery of degraded land, adapted from a traditional technique from Yatenga in northern Burkina Faso.
- Half-moon water catchments in agricultural fields, similar to *zaï* pits but shallower and broader.
- Stone bunds to reduce overland flow after rain, reducing erosion and increasing water infiltration.
- Composting, practised either in heaps or pits.
- Mulching, using a layer some 2 cm thick of dry grass, equivalent to 3–6 t/ha.
- Charcoal making, including from agricultural by-products, using small metal kilns.
- Farmer managed natural regeneration, i.e. selecting, protecting and pruning native trees.
- Grass strips to prevent soil erosion.
- Fencing, to protect and allow natural regeneration in identified areas.
- Fire breaks to prevent bush fires spreading, and the creation of surveillance teams to monitor and extinguish fires.
- Improved cook stoves made from local clay, straw and dung, to reduce use of wood fuel.

Respondents focused on techniques that improve crop yields; few showed concern for the restoration of land and forests. Many farmers considered that the presence of trees reduces agricultural production and so were not in favour of farmer managed natural regeneration (FMNR). The characteristics of restoration techniques influence their adoption. For instance, agroforestry practices, including FMNR, as well as fencing as practised in the study sites (exclosures of 3 hectares) require sufficiently large areas of land and secure land tenure. Composting requires adequate access to organic waste, and the creation of stone bunds demands access to stones and a means of transporting them to the field. Some techniques, such as fencing and charcoal making, require financial capital to purchase materials and are thus commonly financed and carried out by groups that can raise the necessary capital, rather than by individuals.

Factors influencing adoption

All of these requirements pose potential constraints to adoption, which are also different for men, women and young people. Local men and women identified five groups with different capacities for adopting land restoration techniques: (i) male heads of household (*kãsmdambã*); (ii) male youth (*yapnã*); (iii) female farm heads (*pagb sen koodb ye*); (iv) widows (*pug-kõapã*); and (v) wives of migrant husbands (Table 1).

Table 1. Adoption of restoration techniques amongst five different social groups of women and men in Zitenga

	Male heads of household (kãsmdambã)	Male youth (yapã)	Female farm heads (pagb sen koodb ye)	Widows (pug-kõapã)	Wives of migrant husbands
FMNR	√		√	√	
Zaï pits	√		√		√
Half-moons	√				
Stone bunds	√		√		
Grass strips	√		√		

Of the five groups, male heads of households (*kãsmdambã*) have the most resources and knowledge to mobilize in restoration activities. For example, in addition to their rights to land, they have privileged access to their household's organic waste due to their status as household heads, and they can access animal dung due to their livestock rearing activities. As members of informal farmer organizations that receive NGO support, they have access to equipment and transportation for building stone bunds, and to training in restoration activities. They are also able to ask for help from other household members to carry out labour-intensive activities, such as digging *zaï* pits. This is not the case for young men (*yapã*), who migrate seasonally, and have limited access to land and resources, and limited capacity to mobilize the labour of other household members in restoration. The absence of these young migrants during the time of land preparation further limits their ability to invest their own labour in land restoration practices and restricts their familiarity with and knowledge of these practices.

Women also face many constraints to implementing restoration practices, as they do not enjoy the same rights and resources as their male counterparts due to entrenched gender norms. Gender is an

important part of determining who does what, who makes what decisions, and who has access to resources, including benefits from restoration initiatives. For instance, in the study sites, farmers need to vouch for each other's capacities and reliability in order to join informal groups (farmer organizations) that will receive the support of NGOs. Through NGO support, they can obtain material and financial resources as well as training. Due to customary norms, women are not considered eligible to join these groups unless they live with an adult man (husband or son) who can vouch for them and support them with their labour. Widows and wives whose husbands have migrated and who do not have adult sons thus tend to be excluded.

Gender is not the only factor that determines who will implement and potentially benefit from restoration practices. Whether a woman is married, where her husband resides, the size of the plots she has access to, and even whether she has adult male children can all influence the probability of her implementing restoration practices and gaining some of the benefits. Notable differences exist among groups of women, such as female farm heads (*pagb sen koodb ye*), widows (*pug-kõapã*), and women of migrant husbands.

Women who are heads of households (*pagb sen koodb ye*) do not work under the authority of their husbands, even though the husbands are present. This is a recent dynamic with a different organization of farm work and access to land; some polygamous male household heads subdivide family fields among their wives for each to cultivate with their children. These women have the power to decide what to grow and what practices to adopt on their plots. They tend to be members of farmer organizations, and this support helps them overcome the constraints associated with certain techniques, including *zaï* pits, stone bunds and grass strips. An exception is the half-moon, which requires a great deal of labour and compost and which is rarely implemented in the Central Plateau villages. The *pagb sen koodb ye* group demonstrates that women are increasingly responsible for household food security, especially in polygamous households. Yet, although their decision-making capacity is strengthened in light of their added responsibilities, their land status remains unchanged. As wives, they do not own land, and the land allocated to them may be of average quality at best.

Zaï pits dug in women's collective fields. Photo: Marlene Elias / Alliance of Bioversity International and CIAT

The widows (*pug-kõapã*) in the study were mainly 40 to 65 years of age. Those who live with the families of their spouses do not systematically benefit from their former husbands' fields. They cultivate plots that their husbands's family has given them and often find themselves with only small areas of degraded and less productive land. This group has the most

Improved cook stoves, reducing use of wood fuel. Photo: Barbara Vinceti / Alliance of Bioversity International and CIAT

difficulty in adopting restoration techniques. Having male adult children confers advantages, such as membership in a farmer organization; as noted above, widows without sons are indirectly excluded. Status and access to resources further diminish with age. All the widows in the study knew the *zaï* technique, which they say they learned from their late husbands. They are automatically excluded from practising fencing techniques, however, because they do not have enough land to make fencing practical. Stone bunds were implemented only by members of farmer organizations, who can count on the help of adult sons for physical strength, and on NGO support to farmer organization members to transport the stones. Finally, widows who are not part of farmer organizations targeted by NGOs lacked the knowledge to practise FMNR.

Wives of migrant husbands interviewed in the study were mostly 30 to 40 years old, and they cultivated fields that their husbands had inherited. These fields are larger and more fertile than those of widows. The situation of these wives allows them a certain autonomy in managing agricultural work in their husband's absence. This group of women used *zaï* pits and had some rights to use compost if they lived in the compound of their husband's parents. Factors that hampered the adoption of stone bunds, half-moons, FMNR and fencing are these women's lack of membership in farmer organizations, the unavailability of their husband's labour, and the limited size of their land.

Overcoming constraints to women's involvement

These studies showed that most women face important constraints in carrying out restoration activities. Socio-cultural norms and gendered power relations shape women's socio-economic role in society and limit their recognition as legitimate stakeholders in restoration processes. This is reflected by

Mulching, using a layer of dry grass, in a fenced plot managed by women. Photo: Barbara Vinceti / Alliance of Bioversity International and CIAT

women's lack of secure access to land; high levels of illiteracy; poor access to technical knowledge; economic dependence; low productivity due to limited access to assets, labour and inputs; lack of social power; limited participation in decision-making at the family and village level; and scarce time to devote to training in new techniques.

Women also face another set of constraints, including a lack of coordination between organizations, a disregard of their real needs and priorities, and delays in disbursements for financing agricultural tools. Gender inequalities further result in the benefits of interventions being skewed in favour of men over women, which has a major impact on women's productivity. Despite the many barriers they face in engaging in restoration, however, women can see a significant impact on their lives when they are able to practise restoration activities.

To address these constraints, women's self-help groups, with the support of some NGOs (such as Association Tiipaalga), are working to secure communal access to land for women's groups. The groups are primarily composed of widows and young women whose husbands have migrated. NGOs act as intermediaries between land-owners and women's groups to help the latter acquire rights to land. Some women's groups also secure land by maintaining good relations with land-owners and offering their labour — sowing crops or harvesting — in exchange for access to plots. Other women's groups (Nabonswendé, Neblaboum, Wend-Penga and Nongtaaba), acquired land through their members' husbands, who they collectively help with farming at the beginning or end of the agricultural season. Once women acquire land, they fence it off to promote natural regeneration. They also plant species of trees and crops that offer income-generating opportunities.

The support of NGOs and adoption of restoration practices can make an important contribution to improving women's living conditions. As noted above, at the social level, forming groups to engage in restoration is a means to improve women's access and rights to land and other resources. Such groups also facilitate the acquisition of farming implements. One 31-year-old in Gantodogo explained how thanks, to her membership of the group and the interventions of Association Tiipaalga, women have been able to obtain the use of land and loans for buying tools. A 50-year old member concurred, noting that before she joined the group she had no access to carts or wheelbarrows, but now she can do what she wants with the group's cart. In contrast, prior to joining, women had access to agricultural tools only from their husbands, and only when they were not in use.

In addition, Association Tiipaalga trains women in a range of land restoration techniques. Participants can then apply this knowledge to their household fields and personal plots, leading to increased agricultural profitability. In the study villages, restoration activities have also resulted in women's employment and income through the sale of non-timber forest products. Micro-credit provided by NGOs to women's groups has further enabled members to carry out activities likely to improve their income, resulting in an increase in women's individual and collective financial resources. Thanks to this income, women's group members have been able to pursue new small business opportunities.

Conclusions

Social inequalities based on gender, socio-economic status, family structure, and other intersecting factors of social differentiation can strongly influence the ability of farmers to adopt land restoration techniques. Although there are differences across groups of women, the rural women in the study sites generally face several constraints in carrying out activities aimed at restoring land and forests. These are due to discriminatory norms that limit women's access to and control over land, labour and other productive resources, as well as their perceived legitimacy as restoration stakeholders. When women are able to engage in restoration activities, this involvement is accompanied by social and economic benefits, including increased social capital, income and agricultural productivity. Ultimately, the quest for land security and economic opportunities that improve women's living conditions drive their engagement and involvement in land restoration.

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Connecting youth and trees through experience, education and ownership

Peter Borchardt, Mitiku Ketema, Kifle Worku, Shibru Siku, Deresse Kochena & Maximilian Schmid

Tree planting in Libo KemKem, South Gondar. Photo: Plant-for-Ethiopia

Together with the Ethiopian Orthodox Church's Development and Inter-Church Aid Commission and the Konso Development Association, Plant-for-the-Planet Foundation has established a blueprint project for forest landscape restoration. This Plant-for-Ethiopia joint venture has developed a forestry management system and vocational training programme, with new forests providing materials and food, improving biodiversity and soil fertility, and reducing the impacts of climate change. One youth group, which includes up to ten young women and men, planted 36,000 trees in its first years, and is raising approximately 70,000 seedlings for planting in 2021 in South Gondar. As Beru Birhan, a youth group member from Addis Zemen, said, "I have learned such a lot about how to protect the environment and get benefits from it, and am impressed by how degraded areas can be turned into life-supporting land." A second group started in September 2020, with vocational training for all partners through its new tree-planting training facility in Konso, and a third group in Shoa is also forming.

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Key success factors are the complementary experiences of partners, and the fact that youth groups are leasing plantation sites, giving them responsibility for their own forests. Plant-for-the-Planet brings strategic expertise and start-up funding through donations via its app (an open-source platform open to all reforestation projects; see www.trilliontreecampaign.org), with Ethiopian partners working at the grassroots level. A high level of trust exists among all stakeholders, who have been integrated from the outset, including district and village administrations who establish a legal status for sustaining activities.

Through ownership and site-specific management, formerly landless youth are being transformed into tree planters and tree owners, with a new source of income. Nurseries and plantation management create further business opportunities while also building community and environmental resilience. The Ethiopian Orthodox Church is also well known for its ancient church forests, with more than 35,000 of them remaining, though these are under increasing pressure from livestock and cutting for firewood. As part of the project, plantations are planned as buffers, and as corridors to connect these church forests, using local knowledge. This has great potential for upscaling. Gender equality is a further priority and more discussions and enforcement are needed in order to involve women on an equal level.

Tree planting in Libo KemKem, South Gondar. Photo: Plant-for-Ethiopia

Advances in managing and utilizing exotic tree invasions in the Greater Horn of Africa

Nick Pasiecznik, Amsale Shibeshi, John Livingstone & Simon Choge

Clearing farmland in Djibouti invaded by prosopis trees, first by thinning stands for access. Photo: Nick Pasiecznik

"Realizing opportunities to exploit invasive tree resources can create productive and climate-resilient agroforests."

Introduction

Land degradation is associated with deforestation and the expansion of unsustainable agriculture. What receives much less attention is another form of degradation, which results from a massive increase in tree cover. The invasion of exotic woody weeds is a serious issue over many millions of hectares in dryland Africa, and its impacts certainly meet the IUCN definition of land degradation: "a reduction or loss of the biological or economic productivity and complexity of land" (IUCN 2015).

Woody weeds can form impenetrable thickets that have significant negative social, economic and environmental impacts, but they are largely overlooked when targeting areas for restoration. This article focuses on *Prosopis juliflora*, by far the most common

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invasive tree in tropical African drylands, and with some of the efforts made over the past 15 years to achieve the emerging solution of "control by utilization" for livestock fodder, charcoal and other tree products in Djibouti, Ethiopia, Kenya and Somaliland.

The main woody weeds

Tree species of the genus *Prosopis* are the main invasive woody weeds in dryland Africa, as well as in many tropical and sub-tropical dry areas in Asia, Oceania and in their native American ranges. *Prosopis juliflora* dominates in tropical regions worldwide, especially in the Greater Horn of Africa. *P. pallida* is common in a few countries, with *P. glandulosa* and *P. velutina* highly invasive in more sub-tropical climates. Other important exotic invasive woody weeds include *Acacia, Opuntia* and *Parkinsonia* species, among others. Encroachment by native trees and shrubs is also an issue in some areas.

Whether comprised of exotic or indigenous species, however, invasions have similar causes, impacts and scalable solutions. Most *Prosopis* species are tolerant to drought, fast-growing, nitrogen-fixing legume trees. In their native ranges, trees are highly valued for shade and shelter; sweet and nutritious pods for feed; and wood for fuel, poles and quality sawn timber; as well as for honey and many other products (Simpson 1977).

Arrival and spread of prosopis in Africa

Seeing its drought tolerance and use by indigenous peoples, prosopis was introduced to Africa by European colonists, first to Senegal in 1822, then South Africa (circa 1880), Egypt (circa 1900) and Sudan (1917); see Pasiecznik et al. (2001). Most of today's invasions in the Greater Horn of Africa and the Sahel, however, arose from introductions of particularly thorny, shrubby and invasive *Prosopis juliflora* provenances made since the 1970s, especially by well-intended aid organizations in the 1980s to combat desertification and to address "the fuelwood crisis."

Prosopis spread from the original plantations and trial plots. In Baringo County, Kenya, for example, coverage increased from 882 ha in 1988 to 18,792 ha in 2016 (Mbaabu et al. 2019), equivalent to some 650 ha/y. In Ethiopia, it was estimated that prosopis was expanding at a rate of 50,000 ha/y (Yemane 2014). In 2015, there was an estimated 5 million hectares of prosopis in the Greater Horn of Africa and 10 million hectares throughout the continent (Pasiecznik et al. 2015). Extrapolations from recently published papers on expansion rates and others on coverage from remote sensing data in specific sub-national jurisdictions, lead to estimates that there are now at least 10 million hectares of prosopis between Ethiopia, Kenya, Somalia and Sudan, with an additional 1-2 million hectares between Djibouti, Eritrea, South Sudan and Uganda. In the whole of Africa, the area now covered must now be in the range of 20 to 25 million hectares. This is not an insignificant issue.

And it could have been predicted. Native prosopis trees had started invading rangelands, notably in the southwestern United States and South America's Gran Chaco by the mid-1800s, following the introduction of cattle and less use of fire that kills seedlings. Prosopis pods are relished and spread by livestock and other animals and are also spread after rains. Seeds pass through the gut undamaged, and overgrazing increases seedling recruitment as they cannot compete with good grass cover. Overgrazing also leads to the depletion of soil nitrogen; and this, along with more frequent droughts, gives prosopis trees a competitive advantage.

Extensive invaded rangeland in Afar (Ethiopia), suppressing native vegetation (Djibouti), blocking roads (Somaliland), and scrubland with a sign to a training school on prosopis management and utilization (Kenya). Photos: Nick Pasiecznik

Impacts on land degradation

Invasions follow an ecological succession that lead to dense stands in 10 to 15 years. Once established, eradication is impossible — as seen in the USA after decades of knapsack and aerial spraying, and mechanical control (using bulldozers, root ploughs and other heavy machinery), and of failed biological control in Australia and South Africa. Impenetrable thorny thickets reduce pasture potential in rangelands. In cultivated fields they lead to the abandonment of farmland, with invasions also common along watercourses and around towns. And with little else to eat in the dry season, livestock that feed only or largely on prosopis pods can suffer various health problems, leading many people to believe, incorrectly, that pods are poisonous. Invasions reduce native plant biodiversity, lower the water table, block paths and access to water points, and have even forced entire villages to migrate to other locations (Pasiecznik 1999).

Clearing irrigational canals (Somaliland), clearing farmland (Djibouti), cleared farmland back in production (Djibouti), and cleared rangeland with an example of a high-pruned tree (Somaliland). Photos: Nick Pasiecznik

Converting dense thickets to managed agroforests

Studies of the relative costs and benefits of prosopis invasions have come to various conclusions. In Ethiopia and Kenya, for example, income from livestock was reduced over ten years, but there was an increase in income from wood sales (Linders et al. 2020). The proposed solution is to encourage an economic succession, and conversion to open agroforestry systems at tree densities appropriate to each site, between 50 and 250 trees per hectare.

Exotic trees can become invasive because they were not introduced with indigenous knowledge. This was certainly the case with prosopis, as in Africa it is still widely considered a useless weed. In its native range in the Americas, however, pods were an important staple food in the past (Simpson 1977), and are still consumed and commercialized today. Also, for every tonne of pods that is collected and milled, some two million seeds are destroyed, which limits spread. But only since the 2000s has

Collecting abundant pods (Somaliland), in sacks ready for transport (Somaliland), spread out for drying and milling (Djibouti), and milling by a women's cooperative (Somaliland). Photos: Nick Pasiecznik

information in the form of training courses and manuals begun to appear. This includes experiences from Peru, where community associations sustainably manage and make a living from the fuel, fodder, food, honey and timber provided by their native prosopis forests (Parra et al. 2015).

A similar situation occurred with another plant from Peru: the potato. Following its introduction to Europe in the late 1500s, it took almost a century to be widely adopted as a food plant. At first, people ate the fruits and unripe tubers, becoming sick and thinking the plant was poisonous. Today it is the fifth most common food crop in the world. Prosopis pods also have the potential to become a major — and drought-resistant — source of food and fodder (Pasiecznik et al. 2012).

In tropical Africa, prosopis trees are cut with axes or machetes, and people either dig out their roots or burn their stumps . On farmland all trees tend to be cleared, whereas on pasture land, thickets are thinned, leaving selected trees at wide spacings. The cut wood is separated into poles and firewood

Charcoal ready for bagging (Somaliland), and being loaded for sale (Djibouti). Photos: Nick Pasiecznik

or converted to charcoal. The remaining widely spaced trees will also produce much greater yields a much greater yields of pods that are much easier to collect than those from thickets. In Brazil's north-east, prosopis is planted at wide spacings — up to 10x10 metres — specifically for pod production. And one company producing prosopis-based animal feed had an annual turnover of US$6 million in 2010.

Another benefit is climate change mitigation, that would help to meeting nationally determined contributions (NDCs) in line with the Paris Agreement. Geesing et al. (2000) estimated that two tonnes of soil carbon could be sequestered per hectare in plantations through incorporation of leaf litter and root decomposition, and this could also be achieved by thinning invaded thickets.

The potential of improved prosopis management and utilization is clearly enormous, as noted in Pasiecznik et al. (2015):

> "What would you say if you were told that a million tonnes of wheat is produced every year in the Greater Horn of Africa, but is left to rot on the ground? And it is produced without any need for ploughing or sowing, no irrigation, no pesticides, and produces in drought years as well... However, it is becoming increasingly clear that even the most conservative estimates for the production of 'wild' prosopis pods in the region, that yield a flour that is nutritionally equivalent to wheat or maize flour, are at least in this order of magnitude. We are searching for solutions to problems of food insecurity, fodder shortages and unemployment, and answers to problems of climate change adaptation and mitigation. Yet, a large part of the answer is already here, in the 'great green forest' of prosopis that is spreading across the Horn and beyond, also producing at least ten million tonnes of biomass each year."

Promising solutions but persistent challenges

In Ethiopia, FARM Africa and the Afar Prosopis Management Project worked with pastoral communities from the mid-2000s to promote the production of charcoal and prosopis pods for animal feed, with 5,000 hectares of land restored (Kassa 2014). Early results were promising, but were not sustained. In

Goats feeding on milled prosopis pods (Djibouti), and tasting various foods incorporating pod flour (Kenya). Photos: Nick Pasiecznik

addition, a company used milled pod flour in livestock rations for many years, but struggled to ensure consistent supplies. Small-scale production of charcoal and animal feeds is said to be expanding again, although there is no data on volumes produced. However, an economic analysis showed that in Ethiopia, control of prosopis through utilization can be a viable management strategy under the right conditions. This is especially the case for charcoal making, which needs little capital investment, whereas to produce pod flour, changes in production and management are required to make such enterprises profitable (Wakie et al. 2016).

In Kenya in 2006, communities were collecting pods which they sold to a livestock feed company for US$35–55 per tonne. In 2007, 21 tonnes were collected, earning communities more than US$1,000, although problems in agreeing on a price, and with storage and transport, led to the arrangement ending. But groups began collecting again in 2011, with 11 tonnes of pods made into mixed rations and feed blocks for sale in local markets (Choge et al. 2012). And after the Kenyan government legalized the production of prosopis charcoal in 2007, communities earned over US$90,000 per month from sales in the three counties where people were trained to make charcoal. Clearing prosopis trees for charcoal-making also promotes the growth of understorey grasses and discourages the regeneration of prosopis trees (Choge et al. 2012).

Prosopis has one of the hardest and most dimensionally stable timbers in the world, with an attractive reddish colour comparable to rosewoods (*Dalbergia* spp.); it fetches a good price and is in high demand for furniture and flooring in the Americas. Felker (1999) calculated the net profit from timber alone in intercropped prosopis agroforests at 10x10 m spacing to be US$9,774 per hectare over a 30-year rotation (US$326/ha/y), with an internal rate of return of 9.3%. Invasive stands will also produce sawlogs when thinned and pruned to single stems and with similar spacing. The use of chainsaw mills to convert prosopis logs into sawn timber for local use was introduced to Kenya in 2006. Some artisans began to use the wood for carpentry and carvings, but wood-based enterprises did not develop.

Sawing prosopis logs and artisanal carpentry (Kenya). Photos: Nick Pasiecznik

In Djibouti, first supported by UNDP and the Government of Djibouti in 2008 and since 2012 by FAO, communities were provided with mills, tools and training. One cooperative collected six tonnes of pods in 2013, which they milled and distributed to members to feed their animals, and who witnessed an increase in milk yields. They also milled almost three tonnes of pod flour, which they sold for US$1,000 (Choge and Pasiecznik 2014). Charcoal making became another profitable enterprise. However, disputes over ownership and management of the project-donated mills meant that production of flour was not sustained, although charcoal making has expanded.

A regional conference in Addis Ababa (Tsegay et al. 2014) described "control by utilization" initiatives tested in Djibouti, Eritrea, Ethiopia, Kenya, Somaliland and Sudan, including the initiatives discussed above, which confirmed the multiple uses of prosopis and highlighted other successes. However, many of these efforts were not sustained. The overriding reason appeared to be the absence of ongoing support for training in technical and business skills and the lack of markets and appropriate processing machinery.

Recent advances

Building on past experiences, an innovative project in Somaliland (2016–18) has improved food, fodder and fuel security and created employment and new rural enterprises. This was achieved by raising awareness, building capacity in prosopis use and management, and providing hand tools and portable small-scale mills (Pasiecznik 2018). Positive impacts reported by FAO (2020) included the clearance of access roads and irrigation canals, bringing prosopis-invaded farmland back into production, and supporting the recovery of indigenous plants preferred by livestock. Prosopis management also had a positive environmental impact (according to 90% of interviewed households), and reduced flooding. Local cooperatives confirmed the importance of the training in technical and business skills that they received, which helped them to produce and market charcoal and animal feed. A first order for 5 tonnes of milled pods in 2018 was followed by another for 50 tonnes, putting more than US$12,000 into the pockets of local people. Also, interviews with some cooperatives indicated that revenues from charcoal sales far exceeded this amount. The foundation is now laid for the further development of sustainable enterprises that create employment, especially for youth and women.

Conclusions

Improving the management and use of the millions of hectares of prosopis invasions will help to overcome the challenges of food, fodder and fuel insecurity, rural unemployment and migration, land degradation, and climate change adaptation and mitigation. This could generate benefits on a very large scale, but it requires support to mobilize communities, improve local governance, organize and train producer groups in appropriate technologies, and develop new markets and viable enterprises. The following recommendations are proposed:

- Governments, donors and organizations need to support small-scale processing and marketing of innovative fodder, food and other wood and non-wood prosopis products.
- Governments have to formalize, legitimize and regulate sustainable charcoal value chains from prosopis and other woody weeds, and promote the production of processed prosopis pods as viable alternative livestock feed.
- Initiatives such as the African Union's Great Green Wall, UNCCD's Land Degradation Neutrality and NEPAD's AFR100 must incorporate the restoration of invaded drylands into their programming, and encourage the sharing of experiences between countries and continents.

There is an urgent need to come together to create a "great green wall of purpose," identify appropriate drought-proof livelihood options with communities, and scale these efforts throughout the drylands in the Greater Horn and beyond. One of these options is, without doubt, the development of value-added products such as charcoal, livestock fodder, nutritious flour and sawn timber from invaded land, profitably restored and converted into drought-proof agroforestry systems that meet local needs.

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Managing native 'bush encroachment' in East African rangelands

Staline Kibet, Simon Choge, Ross Shackleton & Urs Schaffner

Community members from Nasuulu community wildlife conservancy, Isiolo county, Kenya, manually removing *Acacia reficiens*. Photo: Staline Kibet

African rangelands and savannahs are increasingly suffering from bush encroachment, the invasion by native trees and shrubs in commercial ranching and communal production systems, and also into natural environments. Bush encroachment has major impacts on rural livelihoods by reducing fodder availability, agricultural productivity, groundwater recharge, access to water points and corrals, and tourism. Encroachment has also been linked to reduced plant and animal biodiversity and increases in human-wildlife conflicts. The proliferation of woody species can enhance above-ground carbon stocks, but the impacts on the relatively stable below ground carbon pools remains an area that requires further research.

Bush encroachment has been reported in southern Africa since the mid-1900s, with 73 million hectares now affected in South Africa and 45 million more in Namibia. It is also becoming an increasing threat in the Greater Horn of Africa in recent decades. Although the list of encroaching species is long, *Acacia* spp. and other legumes (Fabaceae) dominate.

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Bush encroachment — largely driven by overgrazing, the suppression of fire, a lack of large browsers (like elephants), changes in rainfall patterns and increases in atmospheric CO_2 — has become a serious management challenge in eastern Africa. This is especially the case in lowland areas, including those in southern Ethiopia, northern and southern Kenya, southwestern Uganda and northern Tanzania, and is an emerging issue in other areas. Problematic species in both Ethiopia and Kenya include; *Acacia drepanolobium, Acacia mellifera, Acacia nubica, Acacia reficiens* and *Euclea divinorum*. In Kenya, *Dodonaea viscosa* is also widespread and a problematic encroacher. In Ethiopia, numerous other trees and shrubs have been reported to be invading rangelands, including, *Acacia bussei, Acacia nilotica, Acacia senegal, Acacia seyal, Acacia tortilis, Commiphora africana* and *Dichrostachys cinerea*.

Traditional control techniques, collectively referred to as "brush management", used prescribed burning, mechanical clearing and herbicide applications, with varying levels of success. Integrated systems are now favoured, that incorporate site-specific knowledge of vegetation, climate, soil and topography to co-manage rangelands for livestock, wildlife and the wider benefits they provide. Integrated approaches including manual clearance, fire and grazing management have increased the scope of brush management from narrow objectives based on cost-benefit calculations to broader aims that include biodiversity conservation and ecosystem services. This now presents many more opportunities to improve the control of native woody species and to better assess and monitor the impacts of interventions, to help ensure increased benefits to people and the environment.

Interviewing community members during manual clearance of *Acacia reficiens* in Isiolo county, Kenya.
Photo: Staline Kibet

Agroforestry: sustainably increasing soil productivity in the West African Sahel

Mike McGahuey

Women transporting firewood for sale. In addition to increasing soil productivity, agroforestry systems produce marketable products that increase and diversify household incomes. Photo: Gray Tappan

"Trees in Sahelian farmlands make a significant impact by adding soil organic matter and providing other services."

Introduction

Sahelian farmers are among the world's poorest. In Niger, for example, smallholders produced an average of only 318 kg of cereals per hectare (ha) from a mean farm size of 2.17 ha, while supporting households of 12 people (Binam et al. 2015). Much of this low productivity is explained by poor soils, small farm sizes, loss of traditional soil restoration systems, and erratic rainfall (Bationo et al. 1998). On the positive side, researchers, practitioners and farmers have made progress in developing approaches to restoring soils, reducing vulnerability to climate shocks and building a foundation for greater productivity.

Key challenges

Increasing soil productivity and reducing vulnerability requires overcoming a complex web of challenges.

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Weathered soils: Africa has some of the world's oldest, most weathered soils; only 10% still have nutrient-rich sediments (Breman et al. 2007). In Sahelian West Africa, 95% of soils are sandy and nutrient poor. Crucially, they are also low in soil organic matter (SOM), which is important for the soils' structural integrity and in the capacity to retain moisture and nutrients in the crops' root zone (Bationo et al. 2005).

An erratic and dynamic climate: Intensive rainfall events pulverize weakly-structured soils, forming crusts with high runoff rates. Dry periods of one week or more weaken or kill newly germinated crops, which then require re-sowing. This shortens the growing season, especially in sandy soils that lack the capacity to retain moisture in the root zone. Consequently, rainfall-use efficiency is very low, with only 15–20% of rainfall used for productive crop growth (Kablan et al. 2008).

High population pressure and loss of fallow: Up until the 1960s, many farmers restored soil productivity by fallowing 2 to 3 hectares for every hectare they cultivated (Jones and Wild 1975). These long fallows, which lasted 5 to 15 years, allowed trees to cycle nutrients from deep soil horizons to the topsoil, reduced erosion, and produced large amounts of biomass that became soil organic matter (SOM). The regenerated trees and shrubs produced wood fuel, fruit and condiments, pharmaceuticals, high-quality animal browse, and construction materials. In years of crop failure these products provided revenue to purchase food. However, since the 1970s, population pressure has forced most farmers to reduce or abandon fallows (Wopereis et al. 2005), weakening their ability to restore soil productivity.

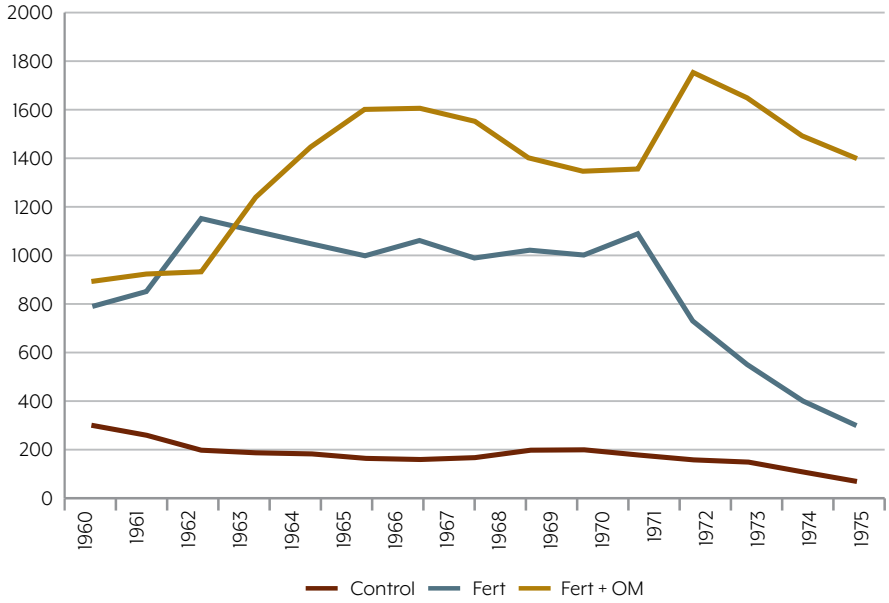
Periodic catastrophic droughts: In the 1970s and early 1980s, recurring droughts coincided with the loss of fallows that had previously served as safety nets during crop failures. Smallholders were forced to sell productive assets and seek paid work to buy food. Food aid became a ubiquitous part of rural life.

Clearing trees: To replace extended fallows as a means to restore soil productivity, Senegal initiated a fertilizer programme, removing field trees to allow easier passage by ploughs. However, these trees had been a part of traditional agroforestry systems that were documented to increase soil productivity by increasing soil organic matter and cycling nutrients (Charreau and Vidal 1965). Fertilizer applications initially increased yields, but the yield response and fertilizer use eventually declined, even with subsidies (Dancette and Sarr 1985). Lack of attention to soil organic matter reduced the efficiency and cost-effectiveness of fertilizers.

Soil organic matter and fertilizer-use efficiency

Long-term research initiated in 1960 at the Saria research station in Burkina Faso tracked yield responses on sandy soils. Figure 1 shows sorghum yields over 15 years, with annual applications of fertilizer plus 5 tonnes of biomass compared to fertilizer application alone, with crop residues annually removed (Pieri 1989). Both approaches produced positive responses in the first three years, but after year four, the yield response to fertilizer alone began to decline while the yield response to fertilizer and biomass continued to increase until reaching 1.4–1.8 t/ha. The FERT yield leveled off over the next eight years and then declined sharply, resembling the response in the Senegal fertilizer initiative discussed above; by the 16th year it was not much higher than the control.

Figure 1: Annual sorghum yield responses (in kg) to fertilizer alone (Fert) and fertilizer with annual application of 5 tonnes of organic matter (Fert + OM) at the Saria Research Station, Burkina Faso, 1960–1975 Source: Pieri (1989).



Research was carried out on the impact of soil organic matter (SOM) on fertilizer-use efficiency in northern Togo. It found that over three years, an average of 41% of applied nitrogen was taken up by the crop on SOM-rich soils, while only 33% was taken up on SOM-poor fields, the difference being greatest in a low rainfall year (Wopereis et al. 2006). In a three-year trial in Niger, researchers found that without fertilizer, millet grain yields on SOM-poor fields were only 150–180 kg/ha, compared to 490–570 kg/ha on SOM-rich fields. Following fertilizer applications, the yields increased to 1,220 and 1,940 kg/ha, respectively, with every kg of nitrogen producing an extra 35 kg of millet grain per ha on the SOM-poor fields, and an extra 47 kg on the SOM-rich fields (Breman et al. 2007).

These experiments demonstrated that soil organic matter had a positive effect on fertilizer-use efficiency and yields, particularly on sandy soils, and by extension, that declining responses to fertilizer in Senegal were related to declining soil organic matter. As Wopereis et al. (2005) observed, the best yields are usually obtained where treatments combine inorganic and organic inputs, with inorganic sources providing necessary nutrients and organic sources helping to increase water retention, strengthen soil structure and increase cation-exchange capacity. Cation-exchange capacity (CEC) is a measure of a soil's capacity to retain critical nutrients; this capacity is highest in organic soils, lowest in sandy soils and intermediate in clays.

The critical role of humus

Most of the benefits from soil organic matter come from humus, the relatively stable organic matter that is left behind after the decomposition by microbiota of SOM's more easily converted substances (Ahn 1970). The properties of humus are particularly important for sandy soils, and directly address key

Early millet under the crowns of *Faidherbia albida* trees in Senegal. Photo: Gray Tappan

challenges faced by smallholders. Humus is "sticky," coating soil particles and binding them together to form crumbs. This is particularly important in stabilizing soil structure and resisting crusting, which affects infiltration and moisture retention in the root zone. Humus holds many times its own weight in water, making it very effective in retaining soil moisture, particularly in sandy soils during extended dry periods. Humus also has a high capacity to retain nutrients and accounts for much, if not most, of a sandy soil's cation-exchange capacity. This explains the high correlation between the SOM content of sandy soils and their fertilizer-use efficiency. Although humus is relatively stable, it is ultimately broken down by soil microbiota, thereby acting as a slow-release source of nutrients.

Increased levels of humus in the soil explain the Fert+OM curve in Figure 1. With the annual addition of biomass, the SOM level was built up over the first several years. This increased CEC and nutrient-retention capacity, increased moisture retention in the root zone and strengthened soil structure. The latter two benefits increased rainfall-use efficiency. In order to receive continued benefits from humus, adequate SOM levels must be maintained through regular applications of biomass. If not, reductions in the amount of humus may lead to spectacular decline in soil productivity (Ahn 1970), as was seen in the fertilizer-only treatment in Figure 1.

Providing soils with sufficient biomass to maintain effective SOM levels is a challenge. The loss of fallows removed a major source of biomass, and crop residue has many competing uses for fodder, construction and cooking (Bationo et al. 2005). However, agroforestry systems have a proven record in providing large quantities of biomass as well as other services.

Fuelwood for sale in Niger. Photo: Chris Reij

Agroforestry systems for biomass and diversification

Research on agroforestry systems shows that they provide services similar to those of extended fallows, including annual supply of the biomass necessary for building and maintaining SOM levels. They also provide marketable tree products that reduce smallholder vulnerability to droughts and other shocks. Two agroforestry systems are important in the Sahel: the traditional *Faidherbia albida* system, and farmer managed natural regeneration, which was introduced in Niger in the mid-1980s.

The *Faidherbia albida* system

Faidherbia albida is a nitrogen-fixing legume. It is the foundation of agroforestry systems across the Sahel and is known to farmers as a multipurpose "fertilizer" tree. It also has the unusual feature of dropping its leaves just prior to the rainy season, providing an ample supply of biomass at precisely the right time; it remains without foliage during the growing season. Felker (1976) summarized three studies in Senegal on the tree's effects on soil characteristics and yields. Compared to soils outside the tree's crown, soils under the canopy had 100% more soil organic matter and higher levels of key nutrients (nitrogen, phosphorus, potassium and sulphur), soil moisture and microbiota (which are important for breaking down complex compounds so that plants can assimilate them). In addition, the partial shade provided by the trees reduced soil temperatures at critical times during crop growth. These factors resulted in grain yields under the tree's crown averaging 900 kg/ha versus 500 kg/ha away from trees. The early advantages to grain crops are particularly important in years of poor rainfall.

Humus content under trees was 1.21% versus 0.85% away from trees, and cation exchange capacity was significantly greater at 42.7 me/kg (me=milliequivalents, used to measure CEC) versus 33.4 me/kg

Faidherbia albida pods, a sought-after livestock feed marketed or used domestically. Photo: Gray Tappan.

(Charreau and Vidal 1965). This could be attributed to the annual production of dry organic matter of 5,350 kg/ha and 11,580 kg/ha, with densities of 20 and 44 mature trees per ha, respectively (Charreau 1974). Note that these quantities exceeded the amount of biomass applied in the Fert+OM treatment in Burkina Faso.

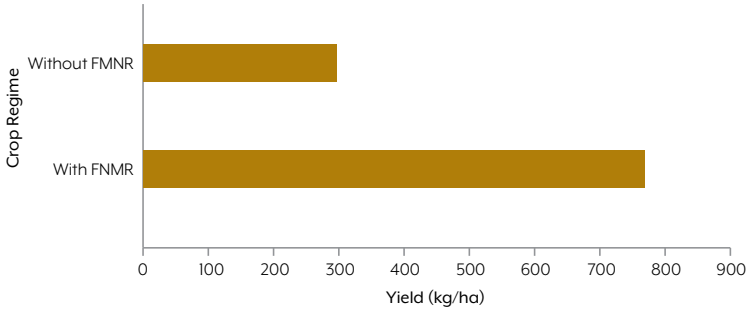
Beyond improving soil productivity, *F. albida* leaves and pods are also a nutritious and economically important browse. During the long dry season, browse makes up to 85%, 50% and 23% of food for goats, sheep and cattle respectively (Fall et al. 2002). *F. albida* pods are particularly sought after due to their high protein content. At a density of 44 mature trees per hectare, *F. albida* produce 175 kg of pods per hectare per year. In years of crop failure, the sale of these pods helps households purchase food and other necessities.

Farmer managed natural regeneration

Farmer managed natural regeneration (FMNR) is an agroforestry system whereby farmers manage trees that they allow to regenerate naturally in their fields. This has positive impacts on soil productivity and vulnerability to shocks. As with *F. albida* systems, FMNR trees mine deeper soil horizons for nutrients and cycle them back to the topsoil. They provide biomass that eventually becomes SOM, and provide products such as fuelwood, browse and foods that are consumed or generate revenue. Trees are pruned back to a few healthy stems just prior to the rainy season. The larger stems and pruned branches are used for wood fuel. Leaf-bearing branches are stripped of their leaves and left on the soil, with branches subsequently used for kindling or fencing. Given that FMNR was initiated and extended in a region with little fallow, it has essentially replaced traditional extended fallows as a means to restore soil productivity.

Improved crop yields are the best proxy for FMNR's impact on soil productivity, such as an almost threefold increase in Senegal from about 300 kg/ha to nearly 800 kg/ha (Figure 2). In addition to increasing yields, FMNR produces fuel, high-quality browse, construction material, marketable fruits, and other products that are less vulnerable to climate and other shocks than annual crops. During a drought in 2004, FMNR farmers generated revenue to purchase food from firewood sales and were less dependent on food aid than non-FMNR farmers were (Abdoulaye and Ibro 2006).

Figure 2. Grain yields on fields with and without FMNR. Source: Beysatol project activity report, October/December 2010, with research conducted by the Senegalese Agricultural Research Institute (ISRA) and World Vision International.



Conclusions

Over the past 60 years, many Sahelian smallholders lost their fallow-based soil restoration systems, which also served as a critical safety net during crop failures and other shocks. Population pressure led to smaller farm sizes and expansion into more marginal land. Recurring droughts forced many people to sell productive assets and seek off-farm work to feed their families. In response, millions of farmers adopted forms of agroforestry to restore soil productivity and reduce vulnerability. These efforts have doubled and even tripled agricultural yields on poor sandy soils. However, meeting the ongoing and worsening challenges of population growth, erratic climate and weathered soils requires that smallholders double or triple those yields once again.

Producing the yields necessary to meet the above challenges is likely to be beyond the ability of agroforestry systems by themselves. Inorganic inputs will also be required, but in the Sahel's weathered and sandy soils, fertilizer-use efficiency will have to increase significantly for those inputs to be economically effective. Agroforestry systems can deliver substantial quantities of biomass to soils at the right time and in the right place, thereby increasing SOM and CEC, improving soil structure and improving both nutrient and rainfall-use efficiencies. In addition, livestock feed, fuel, poles and fruit generate income that smallholders can use to improve livelihoods and reduce farmers' vulnerabilities to climatic and other shocks.

The evidence shows that improving soil productivity and yields is possible by incorporating fertilizer into more intensive agroforestry systems. But, most work in agroforestry and inorganic fertilizers has moved on two separate tracks. Given the high potential for each to complement the other in increasing soil productivity in the Sahel, it is time for researchers, practitioners and farmers to work together to exploit that potential for the benefit of the Sahel's rural poor.

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More trees for more water in drylands: myths and opportunities

Douglas Sheil & Aida Bargués Tobella

Agroforestry parkland, Saponé, Burkina Faso. Photo: Aida Bargués Tobella

"Greater tree cover can reduce or increase water availability, and it is crucial to understand why."

Introduction

The mechanisms by which trees influence water availability remain incompletely understood, but the last two decades have brought astonishing advances. We already know enough to see major opportunities to improve water security in tropical drylands through tree cover, while also yielding the many other benefits that trees provide.

Access to fresh water is one of the UN's Sustainable Development Goals and a foundation for other SDGs. Challenges are considerable, as global water consumption doubles every two decades and global per capita freshwater reserves halved between 1960 and 2016. With population growth and often unreliable rainfall, many people now face intermittent water scarcity and an estimated half a billion already suffer year-round shortages, while droughts cause additional suffering, conflict and migration.

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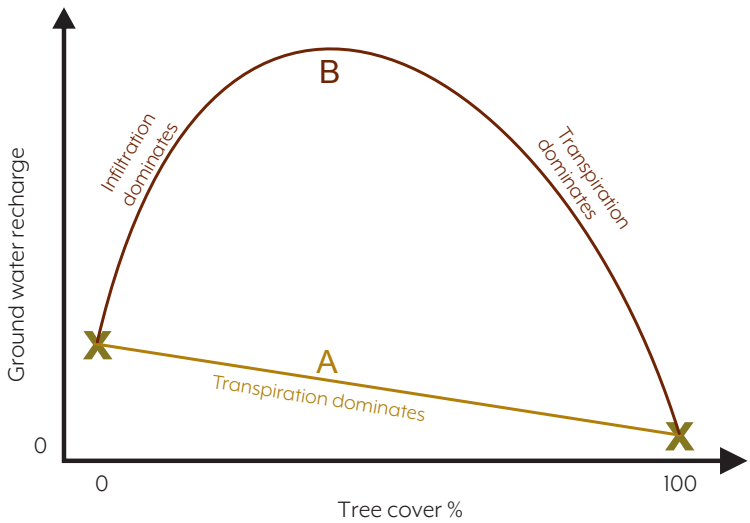
In Africa, these problems are especially urgent. More than 90% of agriculture in sub-Saharan Africa is rainfed and over 40% of the population (approximately 260 million) live in drylands and drought-prone lands. At the same time, Africa possesses considerable potential for increased tree cover, and African drylands are the focus of several ambitious tree-based restoration initiatives.

The restoration of tree cover influences water availability. Many people — some experts, too — believe incorrectly that greater tree cover has an invariably negative impact on local water availability. Where do these beliefs come from? Here we summarize the origin of these misconceptions and illustrate how tree cover can improve water availability. We have recognized the extent of these opportunities only recently, and considerable work remains, but we know enough to dismiss some myths and to highlight major opportunities to improve water security in Africa by restoring degraded landscapes with trees.

Myth makers

The myth that "more trees means less water" has hindered many projects from seeking the benefits of increased tree cover. While various relationships had been suggested over the last century a consensus was sought. This arrived in 2005 in an editorial in *Nature* (Hopkin 2005), which referred approvingly to an article in *Science* (Jackson et al. 2005) informing readers that the authors had "surveyed more than 500 places where new forests have been planted" and that the land became drier and local stream flow declined "by more than 50%." They quoted the first author directly: "It doesn't matter where you are in the world, when you grow trees on croplands, you use more water" (this trade-off is illustrated in Figure 1, line A).

Figure 1. Schematic relationship between tree cover and groundwater recharge.



In recent years many assume, as in line A, that transpiration is proportional to tree cover and dominates the entire range of tree densities; hence, more trees mean less water. More recently, we recognize that in some contexts a small number of trees can have a major positive influence on groundwater recharge (mainly through infiltration and preferential flow) and this can dominate at low tree densities, leading to a strongly non-linear peaked distribution as in line B. Source: drawn by Douglas Sheil.

The study was impressive and persuasive. Some experts raised doubts immediately, but few people heard them, and readers remained unaware that streamflow data derived from just 26 long-term catchment studies, of which 23 included only planted eucalyptus or pine, and only two were in the tropics, while none involved tropical drylands. That the study compared only treeless areas with dense tree stands and neglected intermediate tree densities also went unnoticed. Many readers saw a convincing study with an apparently clear conclusion — more trees mean less water. This message was widely repeated by the popular press and within development agencies. A myth was born.

Myth breakers

New advances and insights correct past misconceptions, and there are many such advances and insights (Sheil 2014; Ellison et al. 2017). The more-trees-means-less-water myth has been debunked many times. We know that increased tree cover often improves water availability. Some increases in drylands are accompanied by observations of greater moisture, such as increased water levels in wells, reduced surface runoff and more greening. Stories like these occur across Africa (Carey 2020). The specific mechanisms behind such observations are seldom obvious without study. Major gains may arise through infiltration and rainfall effects, but other ways that trees bolster water capture are also known.

Often, when trees grow near lakes and oceans, or in highlands, they capture moisture from clouds or fog and channel this into the ground. This has long been recognized in the Canary Islands, in the *Juniperus procera* forests in the Sarawat Mountains of Saudi Arabia, and among the *Tamarix usneoides* trees of coastal Namibia. We lack measurements from African drylands, but elsewhere in the tropics the contribution from droplet capture is sometimes locally significant, particularly when rain is scarce.

In some drylands, the water table lies so far below the surface that only very deep-rooted trees have access to it. Observations show that *Boscia albitrunca* roots can reach 68 m deep in the Kalahari. Many Acacia (*Vachellia*) spp. also possess deep roots that sometimes allow them to reach deep water sources and grow year round. Some trees and shrubs that have access to deeper soil moisture redistribute this water to the topsoil (Kizito et al. 2012).

We now recognize that landscapes with some tree cover can sometimes capture several times more water than otherwise comparable treeless landscapes (Ilstedt et al. 2016). Three years of careful assessment in multiple locations in an agroforestry parkland in Burkina Faso show how trees improve collection of water at the soil surface and reduce runoff, increasing groundwater recharge. In treeless areas only some 10 mm of rain per year replenishes groundwater, but close to trees, groundwater recharge increases dramatically due to improved soil infiltration capacity and preferential flow; i.e., the flow of infiltrating water through macropores such as the channels created by roots and soil fauna (Bargués Tobella et al. 2014). This non-linear influence determines the fate of rainwater up to 25 m away from tree stems, so just a few trees per hectare substantially improve groundwater recharge, and recharge is maximized with an intermediate tree cover (Ilstedt et al. 2016). At this optimum, mean annual recharge is 5 to 6 times greater than in treeless conditions (see Figure 1, line B).

The net effect of trees on groundwater recharge in the Burkina Faso study depends on gains from improved soil hydraulic properties and losses to evapotranspiration; the balance varies with local conditions. Both the optimum tree cover and the magnitude of benefits that result depend on multiple factors, including soil, terrain, rainfall, land use and the nature of the vegetation, but it is clear that

Livestock grazing in the rangelands of Chepareria, West Pokot, Kenya. Photo: Aida Bargués Tobella

greater tree cover can improve recharge over vast regions, especially where land degradation has impaired infiltration (Ilstedt et al. 2016).

The atmospheric water cycle

All trees use water, but recent insights have changed our views on this "use." Long viewed as a "loss," it is now recognized that much rainfall depends on such tree-emitted water. Recent research shows that continental rain depends much more on moisture derived from trees and other deep rooted vegetation than was recognized until a few years ago. Furthermore, intensified recycling means that after water arrives over land, in rain from moist winds or clouds, the presence of more trees means the same water falls more frequently on land before it departs back to the ocean. Observations of increased rain following large-scale reforestation in China appear consistent with this. The water emitted to the atmosphere by trees can be returned with added interest, as the likelihood of rain depends on atmospheric moisture. Meteorologists recognize that in suitable conditions a 10% increase in local relative humidity may increase precipitation by more than 50%.

Furthermore, we now see how some regions depend on rainwater from elsewhere. Since trees bolster atmospheric moisture, greater tree cover increases overall rainfall, though not necessarily in the same location (Sheil 2018). Moisture moves across the entire continent, dependencies varying with location, season and wind patterns, and at times, most rainfall may rely on recycled moisture (Sheil 2019). The value and implications of this crucial source of water needs recognition, while accounting for such transfers requires a continent-wide perspective.

Trees boost rainfall in other ways too. Vegetation contributes to the generation of condensation nuclei — particles that promote cloud formation and rain. Despite advances in understanding their origin, influence and dynamics, their role in dryland rainfall remains unclear (Sheil 2018).

Feedbacks between rainfall and tree cover have become an important focus for climate theorists. One theory invoking powerful feedbacks is the "biotic pump", that explains how tree cover influences pressure gradients that carry winds and moisture across continents (Makarieva et al. 2013). Other theories invoke other mechanisms. Such relationships are increasingly seen as necessary for explaining the abruptness of the monsoons and various other behaviours that remain poorly understood. Yet they are incompletely represented in or absent from conventional climate models, so the implications cannot yet be predicted by simulations. These theories indicate that local climates switch from wetter to drier and vice versa with critical losses or gains in tree cover. If sufficient tree cover was established over broad dryland areas it seems that net rainfall would increase, with the wider benefits that that implies (Sheil 2018; Sheil et al. 2019).

Practical implications

Despite increased knowledge of how tree cover influences water availability, our capacity to guide restoration practices remains limited. See Table 1 for a summary of processes relevant to tree cover.

Table 1. Mechanisms by which trees influence water availability. For additional reviews and references aimed at a non-technical audience, see Ellison et al. (2017) and Sheil (2018).

Mechanism	Scale	Effect	Influences and management implications
Infiltration	Tree and stand	The entry of water into soil, controlling surface runoff generation and soil and groundwater recharge	Soil and rainfall properties; tree roots and litter; tree-associated soil fauna
Preferential flow	Tree and stand	The flow of infiltrating water along preferred pathways in the soil, including macropores formed by roots and soil fauna	Soil properties; tree roots, litter and tree-associated soil fauna
Transpiration	Tree and stand	The process by which trees extract water from the soil or groundwater and emit it to the atmosphere as vapour	Influenced by rooting depth and volume, leaf area and phenology; correlated to canopy cover; reduced by pruning/coppice
Interception	Tree and stand	Prevents some rain reaching the soil surface (evaporates back)	Leaf area and phenology; branch architecture; crown shape; leaf size and orientation; correlated to canopy cover; bark roughness; reduced by pruning/coppicing
Soil evaporation	Tree and stand	Reduced sunlight and cooler understorey temperatures reduce evaporation from the soil surface	Leaf area and phenology; branch architecture; correlated to canopy cover; reduced by pruning/coppicing
Litter mulch	Tree and stand	Affects how much water enters the soil; reduces soil temperature, soil evaporation and surface runoff	Leaf area, lifetime and phenology
Soil water holding capacity	Stand to catchment	Trees often contribute to, and maintain, soils with comparatively good water storage capacity	Soil physical properties, some affected by trees through organic matter inputs and activity of roots and tree-associated soil fauna

Table 1, continued

Mechanism	Scale	Effect	Influences and management implications
Deep water uptake	Tree and stand	Some trees obtain water from much deeper in the soil profile (including groundwater) than other vegetation and can thus emit vapour over more extended periods, which influences atmospheric moisture	This is not the case for seedlings Rooting morphology, tree age/size
Hydraulic redistribution	Tree and stand	Deep-rooted trees, especially those with dimorphic root systems, passively redistribute water from moist to dry soil layers via their roots	Species choices and maturity
Stem water storage	Tree	Trees store water, allowing them to maintain high transpiration for some periods even when uptake from the soil is limited; this allows trees to emit vapour over more extended periods, thus influencing atmospheric moisture	Tree size and species choices; some species, such as baobabs (*Adansonia* spp.) show major adaptations to this strategy
Vapour capture	Leaf and tree (& soil)	Some plants extract water from humid air (some soils are also able to gain moisture directly)	Uncertain, but likely a minor effect in drylands
Dew capture	Tree and stand	Condensation of water vapour is promoted on cool surfaces (shaded places, transpiring stems and from radiative cooling at night); leaf surfaces have been shown to influence dew formation and its capture	Typically minor, but may be locally important; influenced by foliage, architecture and epiphyte load
Cloud capture	Tree and stand	Interception of fog and cloud provides significant amounts of moisture in certain locations/seasons	Locally important (e.g., on coasts and mountains); influenced by tree foliage, architecture and epiphyte load
Aerosols	Stand and region	Plants emit a range of particles and compounds into the atmosphere, which influence when and where water vapour condenses; emissions vary with species, physiology and specific triggers, e.g., heat stress causes some plants to emit isoprene, herbivory can also stimulate various emissions	Largely unknown but likely to be powerful at large scales
Rainfall recycling	Regional	An integrated property that results from many of the others but is also influenced by large-scale atmospheric flow	Increased tree cover typically leads to more effective recycling and a net increase in regional rainfall as water arriving from outside the continent is likely to fall more often before it is lost
Biotic pump	Regional	The theory that suggests that tree cover attracts atmospheric flows from elsewhere by favouring condensation to occur more frequently (a process that leads to lower air pressures)	Increased tree cover will typically increase and stabilize rainfall patterns at regional scales (decreased tree cover reduces rainfall and reliability)

Desirable outcomes from tree cover vary. Some people may want trees to shelter crops or provide fruit, fodder, biomass, wood or other products. Similarly, there are choices about water. Some people wish to increase the recharge of groundwater that feeds wells and springs. Some wish to lower groundwater to avoid salt flows or as a means to reduce mosquitoes — in which cases high evaporative losses through dense cover may be favoured. Some wish to maintain or amplify runoff to feed irrigation, reservoirs or rivers.

Tree and land management — such as tree species selection, land-use practices, grazing and pruning — also influence water availability. For example, pruning reduces transpiration, and current understanding indicates that a broad range of tree cover values may often substantially outperform tree-free landscapes (Ilstedt et al. 2016).

At larger scales, protecting and increasing tree cover sustains and augments vital rainfall. Without detailing the theoretical details and nuances, maintaining significant tree cover upwind, especially near oceans, lakes, mountains or forests, should bolster rainfall across regions and continents, while downwind tree cover protects the atmospheric flows on which we all depend.

Context matters, and the influence of trees on water availability varies over time, space and scale. Water use and related factors and impacts change as seedlings and stands mature. Spatial interactions contribute to distributions such as West Africa's banded and clumped woodlands (*brousse tigrée*). Scale effects are most evident in atmospheric processes — while every tree contributes moisture, marked changes in rainfall require large-scale changes.

Conclusions

The impacts of tree cover on water are often neglected in discussions that surround restoration, and have been misrepresented in global studies on tree-based restoration opportunities. Decision support tools to match trees and management approaches tend to focus on goods (fruit, fodder, timber) and specific services (erosion control, carbon capture) while they neglect water. Every decision to invest in tree cover requires some accounting of the wider implications, and water must be included in this assessment.

Tree cover has considerable potential for improving water security, but how should we promote these benefits? Despite recent advances, much remains to be clarified. There is a need to build knowledge for tailoring guidance to local needs and contexts, and given the stakes, research and collaboration are crucial. We suspect that the protection and restoration of natural vegetation provides more benefits than most alternatives—after all, nature has evolved natural communities as effective systems for sustaining water, and they worked well before humans intervened. Local observations also offer a useful guide to what works in specific locations (Carey 2020). Much remains uncertain and caution is required regarding simplistic claims, but we know enough to dispel myths and to acknowledge and underline that increased tree cover offers a greener wetter world.

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4

International actions and intentions

Photo, previous page: A farmer from Kawitiane village, Senegal, explaining the steps of farmer managed natural regeneration during a joint reflection and learning mission. Photo: Joseph Bidiar/World Vision Senegal

Regreening Africa: a bottom-up transformation of degraded lands

Grace Koech, Leigh Ann Winowiecki, Olaf Westermann, Mieke Bourne, Davis Wamawungo, Sammy Carsan, Tor-Gunnar Vågen, Stephanie Ojee & Susan Chomba

Farmers collecting firewood from a field with naturally regenerated trees in Ghana. Photo: Jason Amoo

"Restoration interventions are as much about people, as they are about changing environments."

Introduction

It is estimated that 20% of global land is either degraded or undergoing degradation, leading to an annual loss of 12 million hectares of productive land (UNCCD 2017). In Africa, some 715 million ha are degraded, including 65% of all arable land, 30% of all grazing land and 20% of all forests. This is due to increasing populations, poor land management, institutional challenges and climate change (Gnacadja and Wiese 2016). The benefits of taking action against land degradation outweigh the costs by up to seven times, implying that inaction will cost countries US$490 billion per year, while action to reverse land degradation could generate benefits worth up to US$1.4 trillion (ELD Initiative 2015).

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Several global initiatives address the threat of land degradation, notably the Bonn Challenge and the New York Declaration on Forests. The UN also declared 2021–2030 the Decade on Ecosystem Restoration, signalling a strong political commitment to restoration for achieving the Sustainable Development Goals. In Africa, there are also the regional AFR100 and Great Green Wall initiatives and a growing number of bilateral projects.

Regreening Africa is a five-year programme (2017–2022) funded by the EU that aims to restore one million hectares and contribute to the livelihoods of 500,000 smallholder farmers across eight African countries; Ethiopia, Ghana, Kenya, Mali, Niger, Rwanda, Senegal and Somalia. It addresses key aspects of land degradation in agricultural lands, such as soil erosion and declining soil fertility, low agricultural productivity, overgrazing and deforestation. It also supports the development of tree-based value chains.

The approach

Many restoration initiatives are characterized by a top-down approach, aggressively promoting one technology or practice as a "silver bullet." But such a focus cannot possibly address the complexity of restoring site-specific ecosystem functions and increasing agroecosystem resilience. That approach also fails to incorporate farmer needs, knowledge and values. Various restoration components do serve specific purposes (erosion control, carbon sequestration, etc.; see Bastin et al. 2019), but care must be taken when using them, such as ensuring that plantations do not replace indigenous species, or that tree planting incentives do not lead to the clearing of natural forests (Holl and Brancalion 2020).

The Regreening Africa programme is valuable in three main ways.

- It integrates cost-effective, farmer-led, gender-responsive restoration options such as farmer managed natural regeneration (FMNR); tree growing; tree-based value chain development; and soil and water conservation practices to enhance agricultural productivity and diversity at the farm level.
- Restoration practices are delivered through scalable models such as the use of lead farmers; farmer-to-farmer training; radio talks/shows in the local languages; use of community videos; establishment of FMNR model sites, rural resource centres and community tree nurseries; exchange programs and site visits; policy influence with community advocacy and action groups; and strengthening of grassroots institutions (mainly village savings and loan associations).
- It uses an adaptive management approach that integrates World Agroforestry's (ICRAF) research expertise, learning and evidence from farmers in the fields and the longstanding experience of international development NGOs to enhance performance. Additional research generated by the Economics of Land Degradation (ELD) Initiative also informs the programme.

ICRAF leads a consortium of international NGOs that comprises World Vision, CARE International, Oxfam, Catholic Relief Services and Sahel Eco. Each of these groups has established networks of national and grassroots influencers such as line government ministries, extension agents, traditional chiefs, lead farmers, rural advisory services and community-based organizations.

Table 1. Technical challenges, strategies, successes and gaps covered by the Regreening Africa project

Restoration challenges	Key strategies	Activities	Gaps to be addressed
• Restoration knowledge, evidence and learning • Capacity in FMNR, tree planting, soil and water conservation	• Improving access to knowledge and skills • Customising and translating guides and manuals to local languages • In-situ grafting to enhance farmer participation	• Farmer-to-farmer or organization-to-organization sharing and learning • FMNR training-of-trainer events • Tree nursery training • Refinement and preparation of technical guides, leaflets and targeted information materials for farmers and extension agents	• Implementors' capacity • "Restoration" meaning different things to different actors • Time lag to benefits • Incentives for lead farmers
• Poor-quality tree seed • Limited diversity for enrichment planting • Invasive species	• High-quality, diverse tree seed and sourcing advice • Seed orchards established • Inventory of existing species and prioritization • Seed collection and storage guides	• Timely sourcing and distribution of planting material • Contracting nursery producers • Seed and nursery guidelines • Follow up and technical support for seedling management	• Limited resources for local seed sources, establishment and maintenance
• Low or no investment in rural delivery infrastructure	• Support to farmer organizations, co-ops, CBOs, etc.	• Support for technical services • Establishing rural resource centres	• Resource constraints in local governments to scale advisory services to all farmers
• Value chain development	• Timber and non-timber value chains scoping assessments	• At least 24 priority value chain options identified for short-, medium- and long-term investment	• Access to finance to reduce the risks for private-sector investments • Low volumes and little aggregation • Poor infrastructure
• Spatial assessment of land health and vegetation cover	• Systematic and crowdsourced monitoring	• Spatial analysis of land health indicators • Making site maps available • A free mobile app to collect data on tree nurseries, tree planting and FMNR • Collecting crowdsourced information to track real-time progress in intervention areas • Co-designed decision processes to engage partners in evidence-based decision making	

Table 1, continued

Restoration challenges	Key strategies	Activities	Gaps to be addressed
• Measurement of household data and socioeconomic outcomes	• Tracking adoption rates of various restoration practices • Measurement of socioeconomic outcomes	• Gender-sensitive, multi-dimensional "regreening action index" developed to measure the extent of engagement in restoration • Annual uptake surveys to measure the adoption rates of promoted technologies	
• Policy shifts needed to accelerate land restoration	• Adopting the SHARED approach to structured stakeholder engagement • Mapping outcomes to track behavioural changes	• Stakeholders identified for engagement through mapping and social network analysis • Policy gaps identified (Bernard et al. 2019) • Outcome mapping used to identify and track progress towards a more conducive enabling environment for scaling restoration	• Policy challenges in land and tree tenure take time to overcome

Monitoring land restoration

Because of the wide differences among degraded sites, the land health status of each site was assessed. This established a baseline from which to track changes and better match restoration practices to local processes and drivers of degradation. Soil organic carbon and soil erosion were assessed using the global network of the World Agroforestry network's Land Degradation Surveillance Framework, and changes in vegetation were assessed using Earth Observation data and field surveys. Data shows that sites in Ethiopia, Ghana, Mali, Niger and Senegal with less vegetation (less than 55% cover) also have low soil organic carbon (less than 13 gC/kg ^{1}, or 1.3%) and a high prevalence of soil erosion (more than 65%).

Table 2: Vegetation cover, soil organic carbon and erosion prevalence across regreening sites in seven countries

Country	Mean fractional vegetation cover (%)	Mean soil organic carbon (gC/kg ^{1})	Mean soil erosion prevalence (%)
Kenya	63	24.8	53
Rwanda	63	20.8	49
Ethiopia	54	12.3	66
Ghana	44	7.3	65
Mali	26	5.4	73
Senegal	11	3.4	68
Niger	3	2.2	84

By combining biophysical and socioeconomic assessments (including community consultations and local expert knowledge), the programme is developing combinations of restoration options that are appropriate to local contexts. Project learning and evidence have helped refine and diversify the recommended options, including FMNR and enrichment planting with multipurpose timber and non-timber trees; soil and water conservation with agroforestry trees and grasses (contour bunding, sand dune stabilization, half-moon catchments and *zaï* pits); exclosures; in-situ grafting and direct sowing; and fire management (table 3). Some of these apply across countries and sites; others, such as exclosures in Ethiopia, are country-specific.

Regreening Africa also uses radio programmes and engages with local governments to scale out to areas beyond the project sites. A total of 9,200 polygons have been mapped using the Regreening Africa app, which enables real-time monitoring of changes in vegetation cover, soil organic carbon and soil erosion.

Table 3: Examples of restoration options evaluated across 8 countries and 23 sites

Restoration options	Ethiopia	Ghana	Kenya	Mali	Niger	Rwanda	Senegal	Somalia
	Oromia, Tigray, Amhara, SNNPR	Bawku West, Garu-Tempane Mion	Migori, Homa Bay	Tominian, Yorosso, Koutiala, San	Simiri, Ouallam, Hamdallaye	Gatsibo, Kayonza, Nyagatare, Bugesera	Kaffrine, Fatick, Kaolack	Baki, Togdheer, Baari, Sanaag
Tree planting, direct sowing, in-situ grafting	✓	✓	✓	✓	✓	✓	✓	✓
Developing a tree-based value chain	✓	✓	✓	✓	✓	✓	✓	✓
Farmer managed natural regeneration	✓	✓	✓	✓	✓		✓	✓
Soil and water conservation	✓			✓	✓	✓		✓
Fire management		✓		✓				
Wood lot establishment	✓		✓			✓		
Boundary tree planting and silvopasture						✓		
Pasture reseeding			✓					

Influencing policy to accelerate adoption and scaling

Effective policies and institutions are critical for adopting and scaling up land restoration, since barriers often exist within policy and institutional frameworks. In many project countries, land restoration policies and development work are poorly aligned and coordinated, and efforts in one sector undermine those in another. Unclear legislation related to land and tree tenure also have a negative impact on investment in forestry and agroforestry, and — more crucially — on the inclusion of women in restoration efforts. Additional barriers identified by stakeholders (including farmers) are inadequate markets and incentives, poor governance and the breakdown of traditional systems, lack of knowledge, limited policy implementation, open grazing, poor communal land management and limited local capacity.

A review of policies showed that agroforestry was mentioned in almost all countries, but only half had specific agroforestry strategies or policies (either finalized or under development). Policies pertaining to tree tenure were also absent in many countries, particularly in the Sahel, but also in Ethiopia. The agriculture or environment sectors generally coordinate agroforestry efforts, but mechanisms to bring in other sectors and stakeholders were largely absent.

Using a structured stakeholder engagement approach (called SHARED), steps were taken to enhance wider shifts in practice and policy. When the programme began, important stakeholders from the local, sub-national and national levels were invited to SHARED national workshops in each country, where they discussed successes, policy gaps and opportunities to support scaling. These culminated in the development of roadmaps to support the scaling of regreening practices that participants were committed to. Together, these initiatives led to the identification of the greatest barriers to scaling restoration, to be influenced through policy dialogues. Outcome mapping is used to track progress towards shifting behaviour and actions in targeted organizations and to achieving policy shifts to create an enabling environment.

A member of Awash Bishola women's group in Ethiopia potting *Grevillea robusta* seedlings. Photo: May Muthuri

Benefits from land restoration

Restoration interventions are more about people than they are about changing environments. Helping communities and farmers become better organized is a lever for transformational change. Such engagements help ensure that rural communities can prosper on their own terms, adapting and responding to changes in and challenges to maintaining land health and biodiversity resources. Restoration plans and practices that integrate trees and shrubs into agricultural and livestock production increase the amount and diversity of crops, forage, timber and non-timber products, and help maintain and regulate critical ecosystem

services such as moderating microclimates, nutrient cycling, flood regulation, pollination and pest management.

At the household level, farmers have started reaping benefits from FMNR, such as firewood from tree pruning and thinning; fodder from grasses, shrubs and pruned trees; timber; poles; fruits and nuts; medicines and green manure. More benefits are expected as better-quality trees grow and bear better-yielding products. In addition, landscape-level benefits — such as the revitalization of ecosystem services through erosion control and enhanced vegetation cover — are being realized, especially from FMNR and from areas restored using half-moons in Niger and stone bunds in Mali.

Financing land restoration

Initiatives need public, private and blended finance to take place at a large scale. Restoration costs vary depending on how it is done, who does it and where. For example, FMNR and assisted natural regeneration are cost effective in restoring drylands, but the costs of raising seedlings, site preparation, planting and tending are very high, and survival rates tend to be low.

Public funding or grants need to balance project-related costs so that these are not consumed by field operations, and to ensure that such initiatives invest more than 60% in restoration activities. There is also a need for a greater understanding of the motivations and business needs of the private sector, and for appropriate engagement strategies, since there is a growing portfolio of green funding for restoration. Whether public or private, funding must ensure that strong social safeguards are in place to protect local communities from exploitation by existing political and economic power dynamics.

In blended finance models, public finance is crucial for the initial stages where processes of multi-stakeholder engagement are built and private-sector finance can then link the products of restoration to markets. In the Regreening Africa programme, private-sector partnerships are explored to strengthen the value chains of high-value tree-based products such as shea, baobab, moringa, parkia (néré), jujube, balanites, cashew, gum arabic, frankincense, mango, avocado and papaya, which can generate economic returns for farmers.

Local community investments in terms of time and labour tend to be undervalued. Restoration processes involving FMNR are seen as "low cost" when these costs are not included in budgets. Another key limitation of current funding models is their short-term nature (three to five years) and the fact that funding comes to an end before the full benefits are realized. Also, overseas development assistance is declining, and other models of finance are necessary.

Key achievements

Data from the programme's uptake surveys in 2019 and in 2020 (ongoing), alongside real-time monitoring using the Regreening Africa app, show that a diversity of land restoration practices are being taken up. FMNR is the most commonly adopted practice (Niger 94% uptake, Kenya 82%, Mali 74%, Ghana 62%, Rwanda 48%), followed by tree planting (Rwanda 82% uptake, Kenya 63%, Ghana 59%, Mali 54%, Niger 47%). In Kenya, the farmer-to-farmer upscaling model, where lead farmers train other farmers, is effective in enabling the widespread adoption of various technologies. More than 60% of households have already adopted different practices, and 3,044 ha are being restored. In Rwanda, the high number of households practising tree planting was due to the widespread availability of

seedlings from the Rwandan government and local cooperatives, with 88% of households adopting various kinds of restoration practices and 4,784 ha under restoration. Based on survey findings, the project team is reviewing the approaches to scaling to better address existing barriers. The goal is to catalyse behavioural change so that more households will adopt land restoration and to promote learning within project sites.

Conclusions

To guarantee successful and sustainable land restoration and sustainable development, it is important to recognize farmers' roles, and to co-design approaches that take their concerns into consideration, especially their time and labour.

By promoting and adopting bottom-up approaches, it is possible to see land restoration successes from farmers' perspectives.

Advocating for more favourable policies on issues such as land and tree access and tenure within national and sub-national governments is likely to accelerate the adoption of land restoration practices.

Land restoration requires more investment for higher impacts at scale.

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Landscape restoration is more than land restoration: the Dryland Development Programme

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Infiltration pits for soil and water conservation in Dimello sub-watershed, Tigray, Ethiopia. Photo: ICRAF

"Dryland restoration transforms lives and landscapes by building ecosystem and livelihood resilience."

Introduction

Drylands constitute 40% of the Earth's land surface, supporting the livelihoods of almost one-third of the global population (Reynolds et al. 2007). They are under severe pressure from human activities and climate change, with 25–35% now considered as degraded; this is expected to worsen (IUCN 2017). As in other regions, drylands in the Sahel and Horn of Africa suffer from reduced agricultural productivity, food and nutrition insecurity, limited economic development, inadequate water management, declining resilience to climate variability, social and political instability, and human migration (Yirdaw et al. 2014; Delgado et al. 2015).

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The past decade has seen increased attention to and promotion of landscape restoration to address chronic problems of deforestation and degradation, alleviate poverty, and build resilience to climate change (Yirdaw et al. 2014). To be effective, this requires the engagement and participation of all stakeholders, including local communities.

This article presents achievements, impacts, lessons and insights from the Netherlands-funded Drylands Development Programme (DryDev) in facilitating land restoration in the Sahel and Horn of Africa, with a focus on Ethiopia and Kenya. DryDev, which ended in 2019, was a multi-sectoral, multi-partner and multi-country initiative implemented in Burkina Faso, Ethiopia, Kenya, Mali and Niger, targeting semi-arid areas with mean annual rainfall of 400–800 mm. The six-year initiative supported smallholder farmers to pursue contextually appropriate options to make the transition from emergency aid and subsistence farming to sustainable livelihoods.

Approaches and stakeholder engagement

DryDev adopted a sub-catchment/watershed management approach to identify sites and activities, which was crucial, since management of water and hydrological systems is critical for restoring degraded drylands. However, conceptualizing, defining and developing catchments was especially challenging in the Sahelian plains due to expansive geographical coverage. This led to delays in implementation. It was also observed that the success of large development initiatives is contingent on identifying and implementing appropriate innovations that are scalable at the local level.

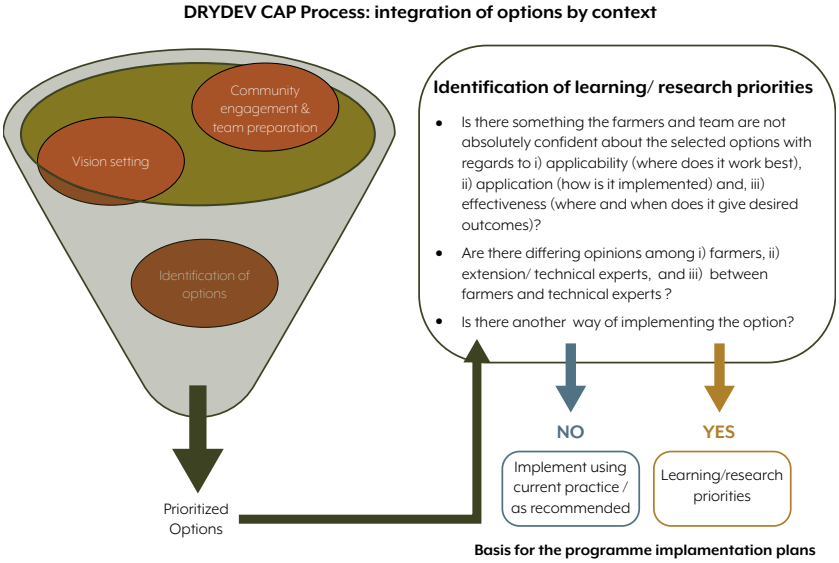
DryDev used an "options by context" approach to promote interventions that were prioritized by smallholder farmers and informed by local realities, and that integrated local and expert knowledge (Figure 1; Coe et al. 2014; Sola et al. 2017). This presupposes community involvement from the outset that upholds key principles of inclusiveness and bottom-up processes. The programme facilitated robust community-level visioning and action planning, involving various categories of farmers to identify options, interventions, learning and research priorities in 29 sites/sub-watersheds in Ethiopia and 28 in Kenya. A co-learning framework was used to select, refine and review the appropriateness and performance of various options. In addition, multi-stakeholder events facilitated sharing and learning at the community, sub-national and national levels (Sola et al. 2017).

The landscape-level sub-catchment management approach requires coordinated and integrated processes to simultaneously address rural economic development, poverty reduction and environmental sustainability goals (Delgado et al. 2015). The programme was guided by three core values — integration, farmer-led processes, and leveraging strategic partnerships — which together facilitated a massive mobilization of people to participate in restoration activities.

In addition, the involvement of sub-national level institutions with adequate capacity was critical for the sustainability of interventions. The programme improved local governance by enhancing the capacity of local duty-bearers. In Ethiopia, this was targeted and driven by district steering committees that were designed to provide support to joint planning, training, and community mobilization. In Kenya, the focus was on establishing, supporting and strengthening farmer organisations, alongside concerted efforts to engage and inform policy makers on issues that constrain land restoration and livelihood development.

Almost 80,000 smallholders were engaged in applying various interventions: 43,922 in Ethiopia and 35,363 in Kenya. Throughout the six years, the target of 50% women engagement in activities was not reached in Ethiopia. Most of the land restoration work was undertaken by men who had more decision making power on land matters and could undertake tasks that needed physical strength. In Kenya, a higher proportion of women — more than 60% — were engaged; most men were often absent, working in the cities. Notwithstanding this, women's empowerment in both countries was one of the major impacts of the programme due to their increased engagement in agriculture production and economic activities.

Figure 1: Community action planning and option prioritization processes. Source: Sola et al. (2017).



Land restoration outcomes and benefits

Increased agriculture productivity

More than half of the targeted farmers were involved in land rehabilitation using terracing, contour ridging, gully reclamation, check and sand dams, tree planting, reseeding grasses and farmer managed natural regeneration (FMNR). These led to improved natural resource management on 50,711 ha in Ethiopia and 13,472 ha in Kenya. This had a huge impact on communities, with degraded areas transformed into productive land, and an increased water supply. Some rehabilitated sub-watersheds, such as Dimello in Tigray, Ethiopia, became learning sites for government agencies and other stakeholders as a model for successful rural development. Implementation of sub-catchment management plans also catalyzed local restoration efforts and sustainable grazing management. Relatively more land was rehabilitated in Ethiopia compared to Kenya, because private and absentee land holdings common in the latter resulted in protracted negotiations that limited rehabilitation and delayed implementation.

Improved grazing management

In Ethiopia, smallholders transformed overgrazed pastures into grasslands by adopting a system of zero grazing plus a cut and carry system for animals at home, which enabled farmers to begin cattle

Maize and potato irrigated using harvested water from rejuvenated springs in Saise Tsaeda Emba, Ethiopia. Photo: ICRAF

fattening and dairy production. In Kenya, farmers reseeded degraded lands, including some crop fields, allowing one women's group of 111 members in Makueni to begin goat breeding, earning an additional US$4,800 per year.

On-farm soil and water conservation

A key goal for DryDev was to support environmentally sustainable food production and water security through climate-smart production practices by investing in on-farm and off-farm soil and water conservation. Rainwater harvesting and constructing storage structures on a cost-sharing basis enabled 12,966 farmers in Ethiopia to begin using irrigation on 4,718 ha, and 2,317 farmers in Kenya on 554 ha. Farmers who constructed *zaï* pits, contour bunds, terraces or infiltration trenches on their fields saw a three-fold increase in yields, to 3–4 tonnes per hectare of maize.

Small-scale irrigation and soil and water conservation techniques improved yields, leading to surpluses, and access to markets through organised groups enabling households to increase income. This in turn reduced youth out-migration to various Gulf states from Tigray and Oromiya in Ethiopia, and to urban areas in Kenya. Participants saw benefits in small-scale commercial agriculture supported by technologies such as farm ponds, water tanks, solar pumps and drip irrigation kits, producing products for insatiable local markets. Two main outcomes were that in Kenya, the number of farmers consuming five or more food groups per day increased by 15% compared to those in non-project sites, and in both countries, women's control over income increased significantly following their involvement in the programme as measured by the Minimum Dietary Diversity for Women indicator. This was catalyzed by capacity building and peer-to-peer training within groups. Efforts were made to prioritie and develop value chains for women, with training in financial management and

Pasture rehabilitation through reseeding grasses and a zero grazing plus a cut and carry system in Makueni, Kenya, before intervention (left) and 12 months after intervention (right). Photos: Caritas Kenya

Climate-smart production options included micro-irrigation from ponds and sand abstraction in combination with drip systems such as tomato under drip irrigation in Jarso, Ethiopia (left), and green gram and maize on ridges and *zaï* pits in Kitui, Kenya (right). Photos: ICRAF

entrepreneurship, and to encourage them to join savings and credit schemes to improve their financial independence.

Lessons and insights

Local governance and institutional mechanisms

Enabling sub-national governance systems can make the ultimate difference. These systems, and the existence of stakeholders with the capacity to engage and leverage resources, played key roles in success. Encouraged by enabling policies on watershed management, DryDev Ethiopia registered impressive results: all 29 target watersheds implemented both biological and physical structures as the first step in the programme's sequential approach. This started with watershed management, followed by on-farm soil and water conservation, climate-smart production, and finally market and financial linkages. These achievements were extensively supported by empowering sub-watershed management committees. Their responsibilities included mobilizing communities, developing local bylaws to control land degradation in communal areas, and overseeing the development and maintenance of infrastructure.

In contrast, Kenya did not have an adequate guiding framework for watershed management. The national Water Act requires that sub-catchment management plans are developed and implemented by water resource users' associations. However, these associations were constrained by a lack of understanding of legislative provisions regarding their mandate and legitimacy. But by the end of the programme this was clearer due to formal registration and training. These efforts in turn facilitated the rehabilitation of riparian land, complementing work by farmer organizations in open areas that showed the opportunities for significant scaling up.

Land tenure and land policy can pose challenges to restoration efforts. Most DryDev sites in eastern Kenya were under private land ownership, with many absentee landowners, which constrained farmers' ability to manage landscapes for the common good. The initial focus on on-farm activities became a key entry point, with water harvesting using farm ponds; later, off-farm water buffering using sand dams incentivized farmers. Ultimately, communities, government agencies and private-sector actors

Land rehabilitation for increased productivity using soil and water conservation measures, FMNR and enrichment planting in Machakos, Kenya, during intervention (left) and two years after intervention (right).
Photos: World Vision Australia

and water users' associations were supported to implement an integrated approach of terracing, water conservation, enrichment tree planting and FMNR, and some areas became learning sites that attracted both national and international visitors.

Strategic partnerships increase impact and scaling

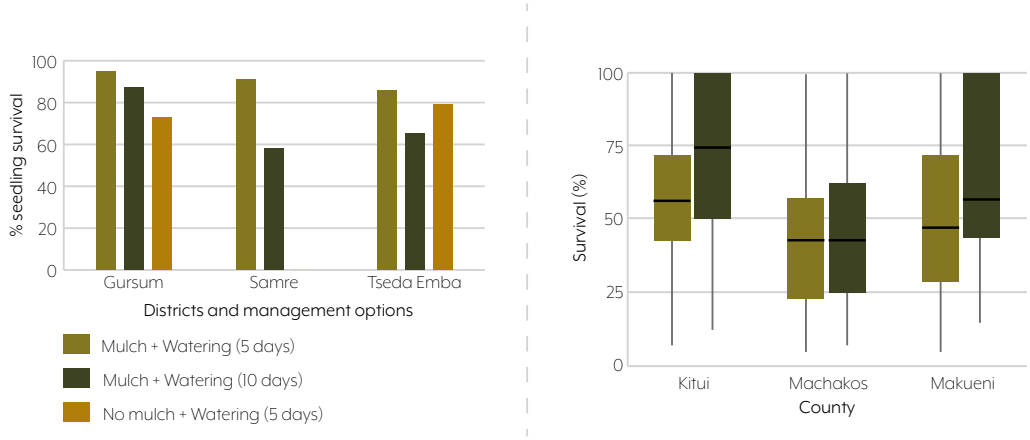
Leveraging resources through partnerships was a key strategy that increased access to extension and technical support. In Ethiopia, regional and local governments leveraged financial, technical and social support schemes including the Productive Safety Net Programme to support large rainwater harvesting structures such as check dams. However, it was difficult to adapt and scale up successes to other countries that did not have similar or adaptable governance systems. In Kenya, devolution began only as the programme was being launched, and new sub-national governments could not offer much support until the final three years. Country consortia were nonetheless quick to adopt a model that integrated farmer-to-farmer extension, which catalyzed engagement and included the training of 35,363 smallholders (65% of whom were women).

Land rehabilitation and water buffering with check dams in Tigray, Ethiopia, with support from district governments and the Relief Society of Tigray (REST). Photo: REST

Generating evidence for learning and scaling

Tree planting is commonly the main intervention in landscape restoration, but in drylands there are significant challenges relating to poor seedling survival and growth. These are attributed to erratic rainfall, planting of ecologically unsuitable tree species, poor quality seedlings, and poor tree seedling management practices (Magaju et al. 2019). Innovative methods were co-designed and implemented with farmers as part of the co-learning and action research component of the programme (Coe et al. 2017). Tree planting "planned comparisons" were undertaken with co-funding from a parallel EC-funded project engaging 1,906 farmers in Kenya and 260 in Ethiopia. Farmers tested different mulching materials, watering regimes, manure application and planting hole sizes. Best practices led to survival rates after 15 months in Ethiopia of 57–90%, compared to the usual 30%, with 8–20% increases in survival in Kenya over a similar period (Figure 2a and 2b).

Figure 2a and 2b: Seedling survival rates from planned comparisons in Ethiopia (left) and Kenya (right). Source: Magaju et al. (2019)



In Kenya, species included *Azadirachta indica, Calliandra calothyrsus, Carica papaya, Mangifera indica, Melia volkensii*, *Moringa oleifera* and *Senna siamea*. In Ethiopia they mostly included *Faidherbia albida, Grevillea robusta, Mangifera indica, Moringa stenopetala, Olea europea, Persea americana* and *Psidium guajava*. In addition, tree planting was undertaken together with FMNR, an option referred to as "FMNR plus" that was implemented on 8,000 ha in Ethiopia and 1,670 ha in Kenya. By the end of the programme, 3,320,895 trees had been planted on farmland or communal areas in Ethiopia, and 164,658 in Kenya. In one district (Samre, Ethiopia) more than 2,000 naturally regenerating seedlings, saplings and trees of 11 woody and shrub species were recorded in a single plot.

Conclusions

There were four main lessons. First, access to inputs — including tree genetic resources, technologies and finances — is a crucial incentive and enabler for implementing dryland restoration. Second, success is contingent on appropriate policy and institutional mechanisms that facilitate community participation, and on resource leverage to increase technology adoption and restoration at scale. Third, tailoring of interventions to the local context, evidence generation and collaborative learning with farmers and other stakeholders are critical for increased adoption and scaling. Fourth, smallholder

access to extension services can be increased by participants joining farmer organizations, with an observed increase of 18% in households accessing extension in project areas in Ethiopia, and a 2% increase in Kenya where farmers were already working in groups.

In summary, designing a successful drylands development intervention with landscape restoration as a major focus is contingent on selecting the right mix of environmental, agronomic, economic and institutional options to address and target the drivers of degradation (Yirdaw et al. 2014). These options must be tailored to local contexts, must be affordable, and must generate tangible benefits to encourage participation. They must also be supported by a community-based advisory system such as farmer-to-farmer extension to facilitate access to information.

Financing dryland restoration for impact at scale is critical. It requires large, integrated and long-term investments that are beyond the scope and duration of most projects. This calls for public-private partnerships that can catalyze technological innovations, leverage resources, help people learn and engage and scale up and out beyond a project's target landscape and country. After all, the benefits of restoration far outweigh the costs of degradation and the losses that accrue from inaction (Yardaw et al. 2014; Mulinge et al. 2016).

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"Build on the rich experiences of truly successful grassroots restoration"

Interview with **Dennis Garrity**

Parkland renaissance on farmland in Niger. Photo: Charlie Pye-Smith

What has worked and not worked regarding landscape-level restoration?

We've learned a lot in recent years about how large-scale land restoration can be successful. That's because there have been some amazing successes that have taught us important lessons about how to foster the process. Perhaps the most instructive case has been the widespread adoption of farmer-managed natural regeneration (FMNR) by millions of farmers in Niger, Mali and across the Sahel. Culturing trees on farmlands had been discouraged by forestry laws that had dictated that the state owned all trees, even on farmer's fields. But when these draconian regulations were relaxed there was a gradual explosion of the practice during recent decades;[1] such that now we find that farmlands in the region have 16% tree cover on average.[2] This occurred with little external investment, because FMNR was a simple practice with multiple and visible benefits for those practising it.

The restoration of traditional silvopastoral systems across large areas in northwest Tanzania, and of natural vegetation on millions of hectares in Ethiopia, are examples of success through community mobilization. We've learned that the best starting point is to build on previous successes, and to foster grassroots movements to drive the spread of restoration solutions. This is best supported by ensuring

Dennis Garrity, Chair of the Global EverGreening Alliance and of Landcare International, and former Director General of World Agroforestry Centre (ICRAF) (2001–2011). Dennis is based in Nairobi, Kenya.

an enabling policy environment, creating effective communications, strengthening value chains so people can market more products from their restored landscapes, and continuing to fill knowledge gaps to support grassroots efforts. These guidelines are known as the Six Steps to Success.[3]

What priority interventions would trigger and accelerate the scaling up of restoration?

We launched the *EverGreening the Earth Campaign* at the New York Climate Summit in September 2019 to be the grand trigger. The campaign is now mobilizing massive efforts to restore degraded forests and agricultural and grazing land, using what we've already learned but on a much bigger scale. The initiative seeks to draw down vast amounts of carbon into regenerated landscapes, while ensuring synergistic benefits to rural people, particularly the least well-off inhabitants of the African drylands.

Farmer managed natural regeneration of trees has been massively upscaled on farmland across the Sahel, as here with *Faidherbia albida* near Bambey, Senegal. Photo: Gray Tappan

The campaign is being spearheaded by the Global EverGreening Alliance, whose 50 members include nearly all of the major development and conservation NGOs around the world. They have pledged their joint capacity to restoring hundreds of millions of hectares of degraded lands through the spread of tree-based systems.

The goal of the campaign is to capture 20 billion tonnes of CO_2 annually from the atmosphere by the year 2050 through landscape restoration processes. It focuses on achieving six targets that emphasize CO_2 capture by scaling up highly cost-effective evergreening solutions. These include assisted natural regeneration of forest lands, farmer managed natural regeneration of trees on farmlands, incorporation of leguminous shrubs into agricultural systems, and regeneration of pastoral systems through silvopastoral practices. All of these have already been scaled across tens of millions of hectares, and proven very effective in improving livelihoods and resilience of the poorest people in the developing world.

The alliance has spearheaded several other major multi-country evergreening programmes now being implemented, particularly in Africa's drylands. It works closely with the African Forest Landscape Restoration Initiative (AFR100), emphasizing learning from, and scaling of, the most inspiring successes. For example, the annual burning of one billion hectares of African rangelands promotes pasture regrowth, but reduces soil carbon and severely degrades land over time. Burning can be replaced by holistic systems of planned grazing that regenerate land, build up soil organic matter and increase pasture productivity. Pastoralist-managed natural regeneration will restore a healthy balance of grass, trees and bushes, enhance fodder production, and improve the microclimate to increase animal welfare and productivity. Our target is to regenerate 20% of Africa's degraded rangelands by 2050 by scaling of these successful systems, and restore the remaining 80% by 2100.

What can governments, the UN, donors and regional agencies do differently or additionally to further support restoration?

Unfortunately, most large-scale attempts at land restoration had disappointing results, or were disastrously unsuccessful. As they were implemented top down with little care or awareness of local realities, the practices used were rarely suited to people's needs, too costly to be sustainable or scalable, and disregarded local land tenure systems. Promotion of plantations of exotic species is another common 'solution', with billions of dollars wasted in such schemes, often supported by multilateral banks and development agencies.

Countries cannot afford to continue barrelling down this path. And they don't need to. They can benefit from rich experiences of truly successful grassroots restoration implemented at scale. But we need a drastic change in the mindset of governments and development agencies to switch from top-down to grassroots-up approaches. Only then will restoration live up to its promise as a truly exceptional way to support climate change mitigation and adaptation, while improving the lives and livelihoods of hundreds of millions of people. There is emerging evidence that forestry departments are beginning to take these lessons to heart,[4] and we hope that trend will continue during the coming UN Decade on Ecosystem Restoration.

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The Global EverGreening Alliance

Since 2012, the Global EverGreening Alliance (formerly the EverGreen Agriculture Partnership), has brought leading research, technical and development organizations together to improve the sustainability, profitability and reliability of smallholder farming systems. The alliance was established to facilitate a collaborative approach to the global problems of food insecurity, rural poverty, climate change and land degradation, and to develop and implement long-term solutions on a globally significant scale. This is achieved by harnessing the collective energies of its members and building on a shared vision to restore degraded land. Members include World Vision, Oxfam, CARE International, Catholic Relief Services, Conservation International, World Agroforestry (ICRAF), World Resources Institute, The Nature Conservancy, Justdiggit, Concern Worldwide, SOS Sahel and many others.

The alliance is committed to delivering sustainable positive impacts at the grassroots level, and to measuring, verifying and communicating these impacts to donors, governments and other interested parties. To that end, it works closely with technical specialists from key alliance member organizations and with corporate partners and stakeholders from across the globe to develop a multi-faceted web-based platform that supports the scaling-up of farmer managed natural regeneration around the world. This platform is designed to meet the needs of donors, governments, UN agencies, scientific and development organizations, and smallholder farming communities. Using purpose-built phone apps, the progress and impact of projects and initiatives are geospatially tracked in near real time using interactive maps and dashboards. The platform also provides information and decision-making tools, training and capacity building, and facilitates communication and cross-learning.

The alliance has a successful track record, including facilitating the development of the largest FMNR scaling-up project, *Reversing land degradation in Africa through scaling-up evergreen agriculture*. Funded by the European Commission and managed by ICRAF, the project seeks to directly support the uptake of FMNR by 500,000 smallholder farming families on one million hectares of degraded land across eight Sahelian countries.

www.evergreening.org

"Forest landscape restoration is not just about planting trees"

Interview with **Mamadou Moussa Diakhité**

A woman collecting firewood in a forest in Ghana. Photo: TerrAfrica Partnership

What has worked and not worked regarding landscape-level restoration?

One of the first steps taken by the African Forest Landscape Restoration Initiative (AFR100) in restoring forest landscapes has been to conduct national and sub-national assessments that identify which places would be most suitable for the forest landscape restoration (FLR) approach. During such assessments, various stakeholders, such as government agencies, NGOs, communities and the private sector, are involved. This has worked well in most of AFR100's partner countries, where stakeholders rapidly reach a good understanding of the FLR concept, and realize that forest landscape restoration is not just about planting trees. They see that instead, as the definition states, the goal is to "regain ecological integrity and enhance human well-being in deforested or degraded landscapes within biomes with the natural potential to support trees." So while the idea is to protect and support natural forest regeneration in some areas of the landscape — such as around watersheds and rivers — other areas will be designated for agricultural activities, agroforestry, plantations, etc. From our experience, once local stakeholders understand this they show great capacities in planning a range of activities in varied forest landscapes.

Mamadou Moussa Diakhité, Coordinator of AFR100 (the African Forest Landscape Restoration Initiative), hosted by the African Union Development Agency-NEPAD. Mamadou is based in Johannesburg, South Africa.

In terms of FLR implementation, we are, however, still at the beginning. Pilot activities work very well, but it is challenging to cover the whole landscape. For example, in one landscape we succeeded in establishing wood energy plantations with private-sector engagement, while other restoration activities in that same landscape lack investment.

What priority interventions would trigger and accelerate the scaling up of restoration?

In my opinion, interventions and funding by private investors such as small or mid-sized businesses are the best way to kick-start FLR activities in a landscape. Currently those investors are focussing on tree plantations for wood energy and construction timber. The second main area of interest to investors is agroforestry and value chains for forest and farm products, predominately those that target the international market. However, it is important to also create funding opportunities for upscaling other FLR activities, such as through carbon funds. This would help to support activities for the protection and natural regeneration of forests, which are part of the landscape approach and are equally important for biodiversity protection, and would also help in terms of the provision of ecosystem services and natural resources for local populations. Here, I would like to add that while some countries such as Kenya and Ethiopia are able to attract private investors, many others on the continent — such as Niger and others in the Sahel — are struggling to do so because they are considered "risk countries."

Community members in Chad planting trees. Photo: Andrea Borgarello

What can governments, the UN, donors and regional agencies do differently or additionally to further support restoration?

African governments, as well as local NGOs, communities, farmers and even small restoration businesses lack knowledge of potential funding opportunities and also lack the capacity to access them. It is essential to support those stakeholders who are interested in FLR, so they can identify

and access finance, in both Francophone and Anglophone countries. For example, project and funding applications are often available only in English, and stakeholders also have limited capacities for proposal writing. To overcome this, workshops and technical support from donors or technical partners would help. In addition, support has to be provided to so-called "risk countries" and their FLR implementers, in order to help them develop bankable projects that they can successfully "sell" to national and foreign investors and donors.

The AFR100 Initiative: An ecosystem approach to forest and landscape restoration

The AFR100 Initiative is a strong partnership of African governments, local organizations and technical and financial partners. It aims to rehabilitate, regenerate and restore more than 100 million hectares of degraded and deforested landscapes by 2030, which will support the livelihoods and well-being of Africans today and into the future. Every year in Africa, nearly three million hectares of forest are lost, along with an estimated 3% of GDP, through depleted soil nutrients. The result is that nearly two-thirds of Africa's land is now degraded, and millions of people face malnutrition and poverty, often forced to further deforest and overexploit their natural resources in order to survive. Deforestation and degradation also intensify the effects of climate change, hinder economic development, and threaten the ecological functions that are vital to national economies.

This has led to an increasing awareness of forest landscape restoration as a way to generate environmental and socio-economic benefits, and to support progress toward national and international development goals. There are many opportunities to scale up the restoration of deforested and degraded landscapes by catalyzing proven practices such as farmer managed natural regeneration, improved tree and stand management, reforestation, evergreen agriculture with intercropped trees, water harvesting and other land and water management techniques. However, framework conditions such as effective natural resource governance and policy coherence do not often favour restoration at scale. Other barriers also impede progress, including weak institutional coordination, inadequate mechanisms to devolve governance to local resource users, and limited incentives for local and foreign investment in sustainable land management.

Since AFR100 was created in December 2015, 30 African countries have joined the initiative, with pledges to restore a total of 126 million hectares, supported by more than 40 technical and financial partners. The first five years have focused on mobilizing countries and partners, piloting activities, building capacities, and creating a strong international standing and recognition. Participants in technical partnership meetings discuss how best to support countries; restoration assessments have been completed in 18 partner countries with the support of IUCN and its ROAM (restoration opportunities assessment methodology) tool. The World Resource Institute's Global Restoration Initiative has also supported a cohort of young African restoration entrepreneurs through its Land Accelerator programme. A monitoring working group was established in 2020 to develop and roll out a comprehensive system that tracks restoration efforts and measures socioeconomic impacts, as AFR100 increases its emphasis on implementation and scaling.

That more than half of Africa's 54 countries have joined the initiative, and have made progress in the first five years is extremely promising, but countries still face challenges in reaching their restoration targets. AFR100 is working to bridge this gap by organizing knowledge exchanges, and launching a programme to train more than 10,000 entrepreneurs in the coming years. A finance working group will support countries in developing tailored financing strategies, with further training and South-South exchanges to build technical restoration skills. Starting in 2021, AFR100 will also set up national forest landscape restoration platforms for participatory planning and cooperation among multi-sectoral governmental institutions, NGOs, producer organizations, businesses and other stakeholders.

Significant additional work is still needed to take stock of successful cases; expand communication, advocacy and outreach; and further implement comprehensive strategies and concrete plans that promote the adoption of forest landscape restoration practices. However, the AFR100 Initiative is well placed to accelerate restoration, and to play a role in enhancing food security, community resilience and biodiversity conservation; increasing climate change adaptation and mitigation; and combatting drought, desertification and rural poverty.

Source: AUDA-NEPAD/AFR100 Secretariat: Mamadou Moussa Diakhité, Teko Nhlapo, and Petra Lahann

www.afr100.org

"Policy makers are key actors, especially at the regional and continental level"

Interview with **Elvis Paul Tangem**

Construction of half-moons in Burkina Faso. Photo: FAO

What has worked and not worked regarding landscape-level restoration?

Sustainable land management and restoration have come to public attention thanks to the creation of the United Nations Convention to Combat Desertification (UNCCD), to initiatives such as the Great Green Wall (GGW) and in response to the devastating impacts of land degradation, desertification and climate change, especially in Africa's drylands.

What has worked? The most important lesson is to use approaches that build on indigenous knowledge, experiences and leadership. Local people have been busy developing methods based on their own experiments and practices, such as farmer managed natural regeneration, *zaï* pits and half-moon basins; farmers such as the now famous Yacouba Sawadogo showed how they improved crop yields, vegetation and soil fertility. Allied to this, success is linked to civil society organizations, NGOs and community-based groups engaging and mobilizing communities to take their destinies into their own hands, and helping to push the restoration agenda forward.

Elvis Paul Tangem, Coordinator of the African Union's Great Green Wall in the Sahel and Sahara Initiative (GGWSSI). Elvis is based in Addis Ababa, Ethiopia.

What has not worked? Reverse what has worked and we see areas for improvement. Land restoration takes time, involves broad-ranging interventions, and is costly. I cannot say that anything has failed, but I can say that all these areas need more effort, investment and scaling up.

It is essential to recognize that policy makers are key actors, especially at the regional and continent level. Engagement at the highest level — such as the creation of the UNCCD and the Africa Union Head of States and Government Summit that led to the creation of the GGW — brought the issues of land degradation and desertification to the notice of the world, leading to global action. Alongside this comes the need for funding; since its creation, GGW has mobilized more than US$2 billion for land restoration and related activities. Other factors that affect success include effective research, knowledge management, communications and publications, and the development of new transboundary programmes such as the African Forest Landscape Restoration Initiative (AFR100), the African Resilient Landscapes Initiative, Landcare International and the Global EverGreening Alliance.

Women preparing land in Burkina Faso. Photo: FAO

What priority interventions would trigger and accelerate the scaling up of restoration?

To fast-track restoration, certain factors must be put in place. Vertical, horizontal and spontaneous scaling up should be the main approaches. We must adopt a landscape approach to restoration, and that should be done not in isolation, but as part of other multilateral environment agreements, such as the nationally determined contributions and the Paris Agreement, biodiversity conventions, and the integration of forest landscape restoration and land use, land-use change and forestry. We need better synergies and coordination, and the strengthening of regional platforms to transform various small and medium-sized programmes into large-scale initiatives. We also need to invest more in regional rather than national programmes, with centralized coordination, knowledge management and communications.

We need more data from action research, a more effective research-policy interface, and improved evaluation and monitoring. Grassroots actors must have access to empirical data in order to better develop and implement land restoration activities. We must also pay more attention to indigenous and local approaches that work, especially those that focus on economic benefits from trees, shrubs and plants for income generation through forest products and non-timber forest products. New technologies and other innovations offer approaches in sectors such as renewable energy, nature-based tourism, the blue economy and water management. Crucially, dryland restoration requires long-term investment, and private businesses and impact investors should be encouraged to become more involved, with funding from pension funds, green bonds, carbon certificates and other innovative sources.

What can governments, the UN, donors and regional agencies do differently or additionally to further support restoration?

We need strong and action-oriented commitments from policy makers at the national, regional and global level to develop innovative policies that support restoration. These should be implemented and promises must be kept; for example, Paris Agreement financing has yet to arrive, and the US$4 billion promised to GGW at UNFCCC COP 21 in 2015 was never disbursed. Measures should be put in place to hold the international community accountable for such failures. Donor organizations should fund long-term and large-scale transboundary programmes, rather than creating isolated projects that lead to repetition and fragmentation, waste scarce resources, and fail to bring sustainable solutions to land degradation and desertification.

The Great Green Wall for the Sahara and Sahel Initiative

Through its vision of an integrated, prosperous and peaceful Africa, driven by its own citizens, and representing a dynamic force in the international arena, the Great Green Wall for the Sahara and Sahel Initiative (GGWSSI) was adopted by African Union heads of state in 2007. The aim was to reverse land degradation and desertification, address biodiversity loss, boost food security, and support local communities and ecosystems to adapt and be resilient to climate change. Initially conceived as a project to replant a 8,000-km corridor 17 km wide from Dakar to Djibouti, it became an overarching platform for enhancing policy advocacy and mobilizing resources for sustainable land management and dryland restoration. The initiative has seen millions of hectares restored, trees planted, climate smart agriculture promoted, and food and nutritional security improved, all of which enhance peace and community cohesion. Experiences and lessons in implementation learned from Algeria, Burkina Faso, Cameroon, Chad, Djibouti, Egypt, Eritrea, Ethiopia, Ghana, Libya, Mali, Mauritania, Niger, Nigeria, Senegal, Somalia and Tunisia are now being extended to 12 countries in southern Africa.

These are some of the initiative's key achievements:

Policy advocacy. The GGWSSI has brought landscape-level restoration to the attention of policy makers in Africa and throughout the world, spearheaded by African heads of state. Its political and diplomatic advocacy has taken the challenges of land degradation,

desertification, drought and dust storms to the highest levels. In addition, the initiative was created as a global partnership, not only for drylands, but also to support the Rio Conventions (UNCCD, UNFCCC and UNCBD), with more than US$1.5 billion mobilized for implementation and innovation.

Sustainable land management and restoration. Land rehabilitation in GGWSSI countries was reported between 2007 and 2019 on 3.77 million ha, with a further 11.8 million ha restored outside intervention zones. Together with the World Bank/Global Environment Facility's Sahel and West Africa programme in 12 Sahel countries, these efforts have a carbon sequestration potential of approximately 90 mtCO2e, with 1.5 million ha of land now under sustainable management, more than 1 billion trees planted, and 7.9 million direct beneficiaries. The reintroduction of wildlife, such as gazelles, oryx and tortoises in Senegal, is another achievement.

Income generation. Agroforestry and sustainable land management have led to many new job opportunities for rural people and have helped reduce poverty through the production and value-addition of non-timber forest products such as fruit, fodder, honey and gums. Revenues from income-generating activities since 2007 reached some US$90 million across all 11 countries participating in the Sahel.

Capacity building. 100,000 people have received training, including farmers and land users, youth and women, local municipality and government staff. Topics include land restoration, water harvesting, seed collection, plant production, nursery management, fire prevention and control, and business development.

The GGWSSI has huge potential to further enhance restoration and sustainable land management in African drylands. The recent addition to the initiative of countries in southern Africa offers the potential for more innovation, information exchange, learning and cross-fertilization of ideas between member states in this truly pan-African effort.

www.greatgreenwall.org

"We need to work better together and unite our restoration efforts"

Interview with **Nora Berrahmouni**

Fodder harvesting in the second year after land restoration, Gnamanga, Soum Province, Burkina Faso. Photo: FAO-AAD/Moctar Sacand

What has worked and not worked regarding landscape-level restoration?

What has worked? At the political level, clear pledges from African governments are reflected in the Great Green Wall Initiative, the African Forest Landscape Restoration Initiative (AFR100), forest and wildlife strategies and frameworks, and the Pan-African Action Agenda on Ecosystem Restoration for Increased Resilience, among other efforts. At the technical level, we know where and how to restore, based on assessments and lessons learned. Regenerative restoration efforts such as farmer managed natural regeneration (FMNR) have proved to be cost-effective and should be used wherever possible, combined with enrichment sowing and planting where needed using quality planting material and seeds of native adapted species. The use of local knowledge and technologies is crucial, such as traditional half-moons and *zaï* pits and adapted large-scale water harvesting technologies.

At the field level, what clearly works is engaging communities from the start. Community mobilization and capacity building have enabled successes in the Action Against Desertification programme that supported more than one million people across 400 communities in Great Green Wall countries. Communities were consulted on the objectives of restoration, where to restore and what to plant, with

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200 species of trees, shrubs and grasses identified for food, feed and fuel; soil fertility improvement; and production of non-timber forest products such as medicines and gums, all managed and monitored by community management committees. Building back biodiversity in the landscape is also key to resilience and livelihoods, and this is why the capacities of local communities and local seed centres were strengthened to harvest and manage seeds in a science-based manner. And not forgetting the need to address restoration along the whole value chain, and provide support to communities in enterprise development for the sustainable production, processing, value addition and trade of forest and landscape products.

What did not work? There is still much to do to address the root causes or drivers of degradation; increase cross-sectoral work, ownership and coordination; sustain capacity building; support evidence-based monitoring and evaluation; and increase our understanding that restoration is not just about planting trees.

Nora Berrahmouni during an Action Against Desertification steering committee field visit in Burkina Faso. Photo: FAO-AAD

What priority interventions would trigger and accelerate the scaling up of restoration?

Larger and long-term public and private-sector investments are urgently needed and must include a value chain approach in order to address degradation while supporting sustainable incentives for restoration. This needs to include the protection of existing natural ecosystems and to prevent further deforestation or degradation. We need to invest more in capacity assessment and development to improve restoration planning, implementation, monitoring and evaluation. We must also support approaches and strategies to improve the sustainable supply of quality native plant seeds and seedlings for restoration.

We need to strengthen cross-sector coordination on the ground and the engagement of various sectors and other multi-stakeholder platforms and initiatives that could contribute to African dryland restoration. These initiatives provide opportunities for stakeholders and partners to mobilize resources and investments for value chains linked to restoration — including the sustainable production of charcoal, livestock and non-timber forest products — as elements of dryland restoration strategies in Africa. An estimation of future trends in the consumption and production of these products would inform decision making and provide guidance for integrating appropriate policies and implementation of restoration strategies.

What can governments, the UN, donors and regional agencies do differently or additionally to further support restoration?

The overarching need is support for countries in assessing and addressing the drivers of land degradation and deforestation, and developing long-term strategies to address them. We need to work better together and unite our efforts at different levels to scale up technical and financial resources by supporting long-term (10–20 year) landscape restoration programmes, and we must avoid investing in small, short-term scattered projects. The good news is that on 7 September 2020, ministers of 11 GGW countries, the African Union Commission and the Pan-African Agency of the Great Green Wall along with UN organizations and bodies, including FAO, UNEP, UNCCD, UNDP, IFAD and WFP, financial partners (including the European Union, Green Climate Fund and Global Environment Facility) and international financing institutions (the African Development Bank, International Fund for Agricultural Development, World Bank, etc.), together committed to support the development and implementation of an umbrella Great Green Wall programme. In addition, the UN Decade on Ecosystem Restoration (2021–2030) and the UN Decade of Family Farming (2019–2028) — along with AFR100 and the Great Green Wall — are golden opportunities to galvanize partnerships and public and private investment from all sectors of society.

Governments need to harmonize existing restoration initiatives at the national level, through coordinated planning and progress monitoring, and by building synergies. These should include technical and financial contributions to tackle many different challenges at once: climate action, combatting and preventing desertification, biodiversity conservation, sustainable land use, youth employment, gender mainstreaming, job creation, and incentives for farmer mobilization. It includes approaching capacity development in a more comprehensive manner by assessing existing knowledge and education programmes, both formal and informal, on forestry, agriculture and the environment to integrate learning on landscape restoration and mainstreaming it in production sectors. And last but perhaps of most importance to community livelihoods, is support for the development of sustainable and resilient value chains for landscape products and improved ecosystems services.

FAO work supporting landscape restoration in Africa's drylands

FAO supports the African Union Commission, the Pan-African Agency of the Great Green Wall, and member countries in implementing the Great Green Wall for the Sahara and the Sahel Initiative. And through the EU-funded Action Against Desertification programme, 53,000 hectares have been restored across Burkina Faso, Ethiopia, The Gambia, Niger, Nigeria and Senegal, and this work is now being scale out to Eritrea, Mauritania and Sudan with the support of the Turkish-funded Boosting restoration for income, development, generating ecosystem services (BRIDGES) project. Successes and lessons learned from all these initiatives are compiled in the FAO manual, *Restoration in Action against Desertification*, published in 2020.

FAO and the African Union Development Agency - New Partnership for Africa's Development are implementing a regional technical cooperation programme to support the monitoring of AFR100 and to support effective coordination and implementation of commitments. It focuses primarily on an online monitoring and knowledge platform, a regional capacity development plan at the country and regional level, and resource mobilization through regional and country programme portfolios, carried out with technical and financial partners.

At the request of GGW countries and partners , FAO also supports six countries in developing the Scaling-up Resilience in Africa's Great Green Wall proposal for submission to the Green Climate Fund, and supports separate efforts for other countries. FAO is also supporting other dryland countries in preparing the GEF-7 Sustainable Forest Management Impact Programme on Dryland Sustainable Landscapes, to help implementation of the Great Green Wall in the countries of the Southern African Development Community (SADC).

FAO led the *Trees, forests and land use in drylands: a global dryland assessment*, the first study of its kind published in 2019. Building on the data collected, and on further analysis and data collection with member country experts, we estimated that 221 million hectares of African drylands require restoration: 166 million in the Sahara and Sahel region (including North Africa and the Horn of Africa) and 55 million in the the Southern African development Community (SADC) region. FAO also develops global guidelines and provides information and technical support to develop monitoring and evaluation frameworks for forest and landscape restoration, organizes knowledge-sharing events, establishes communities of practice on key forest and landscape restoration topics, and strengthens understanding of the economics of ecosystem restoration. In addition, the FAO library contains many knowledge and technical information products.

www.fao.org/in-action/action-against-desertification

Improving the monitoring of forest and landscape restoration in Africa

Salima Mahamoudou & Bernadette Arakwiye

In Makueni County, Kenya, youth groups run tree nurseries that raise seedlings for restoration projects. Photo: Peter Irungu /WRI

"Without good data, we're flying blind. If you can't see it, you can't solve it." Kofi Annan

Introduction

Restoring degraded land includes growing trees to transform farms, forests and pastures into more productive and resilient ecosystems. Forest and landscape restoration (FLR) is increasingly seen as a key approach to making progress in national food security strategies, poverty reduction and climate resilience (Chazdon 2017). Land restoration is not new to Africa. From Sahelian and East African drylands and savannas to Congo basin tropical forests, many communities have been restoring lands for decades to generate benefits for people and the environment. Prominent examples include farmer managed natural regeneration and assisted natural regeneration in degraded regions. Farmers have increased tree density on farms and pastureland, leading to improvements in household socio-economic conditions (Reij and Garrity 2016).

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Thirty African governments have now committed to restoring deforested and degraded lands as part of global restoration initiatives, including the Bonn Challenge and the New York Declaration on Forests. Several countries, such as Malawi and Madagascar, have developed national restoration strategies, aligning stakeholders from across ministries and industries around a common framework on FLR. Successful implementation will contribute to large-scale increases in tree cover and tangible improvements in environmental conditions (Temperton et al. 2019). At the regional level, the Africa-led AFR100 initiative, under the leadership of the African Union Development Agency-New Partnership for African Development, aims to restore 100 million hectares of deforested and degraded landscapes across the continent by 2030.

But to achieve these ambitious pledges, participants need to understand what has already been done, and to design and implement monitoring systems that track progress in achieving commitments and plans (Hanson et al. 2015; Cristales et al. 2020). Monitoring forest and landscape restoration is, however, not as simple as it may sound (Reytar et al. 2020). Planting and growing trees is just the beginning. It is essential to track tree survival and growth, as well as trees' ability to store carbon and to provide nutritional, economic, biodiversity and other environmental benefits.

Challenges in monitoring restoration

Meeting restoration targets requires a holistic system to track and document progress while consistently improving management practices. Tracking restoration will help governments, local communities and NGOs show the progress made on their commitments and scale up successful projects, and positive results will inspire donors to continue investing (WRI 2020). Measuring progress in Africa can also spotlight farmers and local champions who have restored their land through grassroots approaches. But their successes can be replicated only if practitioners and decision makers understand land restoration's impacts on people and the environment.

With tools such as the Restoration Opportunity Assessment Methodology (ROAM) and the Rapid Restoration Diagnostic (RRD), many African countries have accurately and efficiently mapped trees and assessed opportunities, both nationally and within individual landscapes. As a result, AFR100 restoration commitments have significantly grown and gained momentum (Akinnifesi 2018). However, before starting restoration work, countries must assess the current state of their landscapes to establish a baseline for planning and monitoring progress. Unfortunately, most existing forest monitoring systems were tailored to tracking deforestation, not restoration. The remote sensing techniques that they use fail to detect small or scattered trees, or they assess only tree cover and fail to include the benefits that those trees provide. Most importantly, these systems are often too expensive to operate at scale (Reytar et al. 2020).

Several conventional monitoring frameworks and datasets are relevant to forest and landscape restoration in Africa. They include the Food and Agriculture Organization's Forest Resources Assessment and the IUCN-led Restoration Barometer, both of which compile self-reported statistics from government sources. Freely accessible satellite imagery has also increased the capacity of some African countries to monitor changes in land use (Sloan and Sayer 2015). However, these datasets suffer from a lack of consistency and completeness across entire countries and time spans (Brink and Eva 2009). Furthermore, within countries, data for monitoring restoration is often fragmented and scattered throughout different institutions and ministries, which makes it difficult to comprehensively assess progress.

What is required?

The World Resources Institute's extensive work in countries such as Malawi, which built the first framework in Africa for monitoring a national restoration plan, has made it clear that there is no one-size-fits-all approach (Government of Malawi 2018). Plans to implement large-scale restoration have highlighted gaps in the systems that track progress. First, forest and landscape restoration inherently has a long time horizon; it can take years to observe substantial changes on the ground. Second, restoration objectives can vary widely because they target a range of ecosystems or land uses, they include tree-based and non-tree-based techniques, and they rely on diverse approaches that affect the landscape in different ways. The nature of FLR and its diversity of approaches thus require adaptable monitoring frameworks (WRI 2020).

Effective monitoring systems must be tailored to this complexity. They must also be suited to each country and project's specific needs, contexts and ecosystems (while taking a consistent approach). In addition, measuring progress in tree growth — from seedlings to saplings and from young trees to mature trees — requires monitoring systems that incorporate long-term data. It is thus important to determine what can be detected within the proposed timeframe of an initiative and to select appropriate indicators to monitor (Cristales et al. 2020). Monitoring should always focus on measuring progress toward the specific goals that restoration efforts plan to achieve. In sum, there should be one vision for monitoring effectively, but a variety of approaches at three scales: globally across Africa, within countries and landscapes, and for individual projects (WRI 2020).

Existing tools

The AFR100 initiative could fail to achieve progress or impacts if it does not have flexible monitoring systems. Monitoring systems must be efficient and transparent, must incorporate lessons learned from successes and failures, and must document progress in a credible and compelling way. They also need to attract financial support at a scale consistent with their ambitions. With those criteria in mind, the following text describes the most efficient tools and methodologies to guide African governments, project developers, and entrepreneurs as they build systems to measure progress. Table 1 summarizes these tools.

The Road to Restoration

FAO and the World Resources Institute created this flexible guide. It helps governments and organizations that are restoring land to design a comprehensive system that allows them to make informed decisions and measure progress (Buckingham et al. 2019). It helps practitioners understand the current state of the landscape being restored, identify what they want to achieve, choose the indicators they need to prove success, and develop an actionable strategy for tracking progress (Figure 1). Several countries in Africa, including Ethiopia, Kenya and Malawi, have used this methodology.

Figure 1. The Road to Restoration goal wheel and relevant indicators. Source: Buckingham et al. (2019)

Tree Cover Mapping

This was developed by the United States Geological Survey to map tree cover density at large scales by visually interpreting high-resolution satellite imagery (Cotillon and Mathis 2016). It uses a grid-based sampling approach to produce tree cover maps (Figure 2). It is particularly effective at measuring tree cover density outside forests, such as in agroforestry systems. The tool has been used to map on-farm tree cover in Burkina Faso, Malawi and Niger, and could be used throughout Africa's drylands. The tool can be downloaded as an add-on to the ESRI ArcMap Geographic Information System interface.

Figure 2. The Tree Cover Mapping tool interface, showing a sample plot. Source: modified [by G. Tappan] from graphic in Cotillon and Mathis (2016).

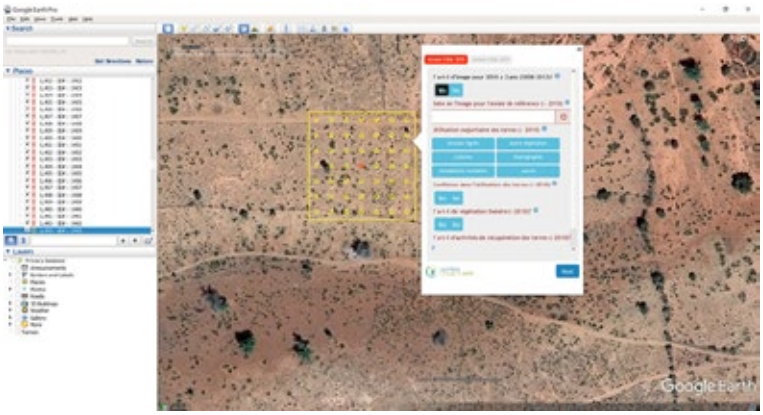
Collect Earth

This user-friendly and participatory mapping and monitoring tool is open source and Java based. It draws on a selection of other software to facilitate data collection. In conjunction with Google Earth, Bing Maps and the Google Earth Engine, it allows users to analyse high- and very-high-resolution satellite imagery in order to collect broad data on the number of trees, tree cover density, infrastructure and land use. It shows changes in a time-efficient and cost-effective way (Figure 3). In a collaborative process called a Mapathon, local experts visually identify features in the landscape, collectively

producing high-quality data that they own. To date, Collect Earth has produced statistics on tree cover and land-use changes in many African countries, including Cameroon, Ethiopia, Kenya, Malawi, Niger and Rwanda.

Collect Earth Online is the web-based version of the tool; it eliminates the need for software installation and data management, and consistently locates, interprets and labels reference data plots for classifying and monitoring changes in land cover and land use.

Figure 3. The Collect Earth monitoring tool interface, showing a sample grid. Source: WRI (2020)



Restoration Mapper

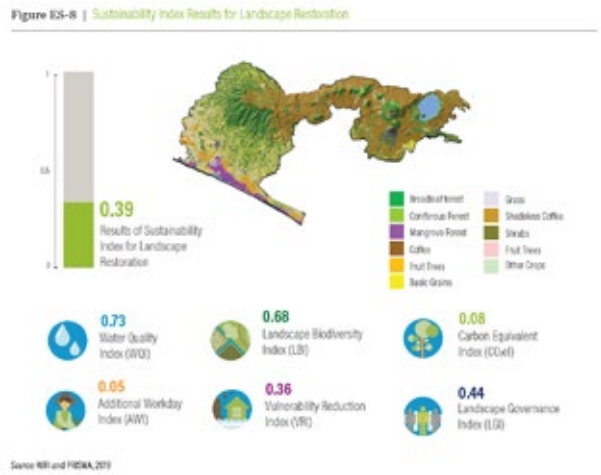
The World Resources Institute (WRI), the University of Copenhagen and NASA are exploring new techniques that use artificial intelligence and apply machine learning to analyze raw satellite data from across the Sahel and other African landscapes (Brandt and Stolle 2020). The goal is to build accurate and comprehensive maps of millions of trees, which have rarely been considered in official statistics, plans and models (Figure 4). So far, WRI has analysed more than 30 landscapes of 10,000 hectares each with this technique. This approach could be improved to determine which tree species are present in the landscape, allowing the development of a more accurate and comprehensive regional database for land restoration in Africa (Miyoshi et al. 2020).

Figure 4. The Restoration Mapper interface, showing tree cover in a part of the Sahel. Source: Brandt and Stolle (2020).

Sustainability Index for Landscape Restoration

This field-tested tool was built from the Road to Restoration guide and created by WRI, PRISMA, GIZ and the Government of El Salvador. It allows governments and project developers to communicate their success by building a Sustainability Index for Landscape Restoration (Figure 5). The index evaluates progress toward the biophysical and social goals that have been set for a given landscape with a simple score (Cristales et al. 2020). The overall score measured by the index can be broken down into various biophysical and socioeconomic components, which allows for a better understanding of the impacts of restoration.

Figure 5. Sustainability Index for Landscape Restoration as applied to El Salvador's El Imposible-Barra de Santiago landscape. Source: Cristales et al. (2020)



TerraMatch

This standardized platform connects projects that grow trees with potential funders — including philanthropists, private companies, and non-governmental organizations — who want to restore degraded land (WRI 2020). After matching funders and projects, TerraMatch collects information on how much funding has been provided to projects (Figure 6). This enables the platform developers at WRI to assess how much finance has flowed and to which type of restoration projects, and TerraMatch is also directly integrating project-level biophysical monitoring.

Figure 6. An overview of the TerraMatch tool. Source: WRI (2020)

Table 1. Summary of scale, strengths and weaknesses of seven restoration monitoring tools

Scale	Strengths	Weaknesses
Road to Restoration		
Landscape and national levels	• Explains the complexity of monitoring restoration through case studies • Step-by-step guide to identify the purpose of restoration, monitoring indicators and the data needed to track progress • Provides examples of indicators to consider when measuring restoration progress • Allows a flexible approach by providing various entry points for considering different goals and targets; e.g., biophysical and social factors, ecosystem goods and services, and goals under UN initiatives • Can be integrated within existing monitoring frameworks	• A guide to creating a monitoring platform, not a platform in itself
Tree Cover Mapping		
Landscape and national levels	• Production of tree cover maps • Allows monitoring of agroforestry systems and trees outside forests	• Reliance on interpretation can affect results and error margins • Requires good internet connection • Adaptable only to an ArcGIS desktop • Reducing error margins requires ground truthing
Collect Earth		
Landscape, national and regional levels	• Produces statistics on tree cover and land-use changes using high-resolution images • Allows monitoring of trees outside forests • Changes in land use and tree cover can be assessed over multiple timeframes • Documented case studies and a community of users	• Requires GIS and coding skills • Reliance on user interpretation can affect results • Reducing error margins requires ground truthing • Requires good internet connection to obtain high-resolution imagery
Collect Earth Online		
Landscape, national and regional levels	• Produces statistics on tree cover and land-use changes using high-resolution images • Allows monitoring of trees outside forests • Easily accessible and user friendly • Multiple users can work on and collect data simultaneously	• Reliance on user interpretation can affect results and increase the error margin • Requires purchase of high-resolution imagery, which makes assessments over multiple timeframes very expensive • Requires good internet connection

Table 1, continued

Scale	Strengths	Weaknesses
Restoration Mapper		
Project, landscape, national and regional levels	• Wall-to-wall maps of trees in arid lands allows users to detect small trees and shrubs • Based on machine learning, which reduces processing time and speeds up calculations	• Requires knowledge of artificial intelligence and machine learning to create algorithms • Requires access to cloud storage capacities • Requires good internet connection
Sustainability Index for Landscape Restoration		
Landscape and national levels	• Uses multiple factors for a better understanding of restoration's impacts on landscapes/sites • Can be adapted to local needs and indicators • User-friendly and easily accessible • Can incorporate existing datasets and monitoring frameworks	• Requires input of high-quality data on climate, soil, water, etc. • Not yet tested in Africa, but applicable in any landscape with enough data
TerraMatch		
Project level	• Easy, transparent data gathering on financial flows and restoration funding sources	• Compiles data only from projects funded through TerraMatch

Restoration monitoring beyond biophysical changes

Assessing physical changes in land use and land cover over time using satellite imagery is the most straightforward indicator of effective restoration. But a robust monitoring system also needs to include other contextual elements, such as these:

- **environmental factors** such as biodiversity and climate protection;
- **socioeconomic factors** such as food security and access to clean water that will indicate whether restoration has achieved its end goals;
- **political will** and favourable policy conditions, which signify sustained commitment to restoration; and
- **stable financial flows** and increased investments, which indicate a willingness to fund long-term work.

The Sustainability Index could effectively aggregate biophysical and socio-economic data to show overall progress, once relevant and available data are collected. Although these dimensions and factors are complex, they are also the basis of successful restoration at scale that will bring positive changes to livelihoods and the environment.

Conclusions

To meet Africa's potential for restoring land at scale, there is an urgent need for a comprehensive vision for monitoring, built on independent data, that does more than just identify areas that would benefit from restoration. African countries should therefore consider devising monitoring systems that align with their national restoration strategies and that ultimately support the goal of restoring 100 million hectares by 2030. This article highlights existing tools and monitoring frameworks that can guide African countries in the development of their monitoring systems at a range of scales. The monitoring of forest and landscape restoration is still a developing field of study, and the following actions would help project managers and countries develop robust systems:

1. Use the Road to Restoration to guide the selection of the main indicators and metrics that reflect local goals.
2. Focus on indicators and metrics that people already know how to collect, when reporting on existing commitments or programmes.
3. Identify data from sustainable sources; i.e., that can be collected systematically for the foreseeable future.
4. Establish the baseline conditions of the land by using tools such as Collect Earth or by extracting information from existing datasets.
5. Use the Sustainable Index for Land Restoration to aggregate the data collected and present it clearly.
6. Monitor changes in indicators and metrics over time and update the index as required.
7. Report progress on restoration through national and international platforms such as the Restoration Barometer.

As an AFR100 partner, WRI is continuing to help governments, independent monitors and local organizations to integrate high-quality data into their monitoring work – and to follow the steps outlined above. By building the capacity of local institutions through targeted training, WRI is dedicated to ensuring that restoration data is locally owned and managed.

The AFR100 Secretariat could support the mainstreaming of such tools and facilitate their implementation in member countries; this would allow consistent tracking of restoration progress across hundreds of landscapes throughout Africa. Investors and funders need to build the costs of high-quality monitoring into their proposals. Finally, it is crucial to remember that although it is essential to have solid data, innovative tools and robust plans, they will be useless unless people and organizations can act on the results on the ground.

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The European Tropical Forest Research Network (ETFRN) was established in 1991 to ensure that research and knowledge effectively contribute to the conservation and sustainable use of forest landscape resources in tropical countries, through a network for communication that promotes dialogue between researchers, policy makers and forest users within and between countries, increases cooperation, collaboration and advocacy support, and provides services for exchanging up-to-date knowledge. This includes ETFRN News – theme-based editions on current issues in international development agendas. This issue presents experiences in restoring African drylands, and provides pointers to progress for scaling up the evident successes.

Tropenbos International (TBI) envisions a future in which forests and trees are used sustainably for the benefit of local people and the global community. By making knowledge work for forests and people, Tropenbos International contributes to inclusive and evidence-based decision making for the improved management and governance of tropical forests. TBI's longstanding local presence and ability to bring together local, national and international partners makes it a trusted partner in sustainable development. TBI hosts the ETFRN Secretariat and co-publishes ETFRN News.

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